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Wind Resource Assessment Over Kutubdia Island, Bangladesh

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Abstract

Kutubdia is one of the coastal Islands in Bangladesh. The wind speed data at the location of the wind monitoring station of Bangladesh Meteorological Department (BMD), Kutubdia appears to be low but at another location, Bangladesh Centre for Advanced Studies (BCAS) finds that the wind energy availability should be reasonably high in Kutubdia. A micro scale prediction has been done using (100 x 100 m^2) grid cells in the Wind Atlas Analysis and Application Program (WAsP), a software package, to develop monthly and annual wind atlas and a wind resource map at 50m height above the ground level over Kutubdia which shows that at 50m height the annual wind speed over Kutubdia coast side varies from 4.5 m/s to 5.5 m/s. Certain locations in southern and eastern sides of Kutubdia where annual wind speed is above 5 m/s appear to be suitable for wind electricity generation. Monthly and annual energy productions have been calculated for a promising location using the power curves of 3 turbines and the WAsP technique. Wind Atlas for Cox's Bazar, a coastal area – around 40 km away from Kutubdia in the south-east direction, has been used to have a second estimate of the wind speed at the locations of Kutubdia at 50m height.

Introduction

Kutubdia, an Island close to the eastern coast of Bangladesh, has an area of 212 sq-km and the population is around 0.12 million. Several rice husking mills, shrimp farms, salt processing plants, primary and higher secondary schools and a health complex are situated in this Island. Bangladesh Meteorological Department (BMD) finds the annual average wind speed over the last ten years (1991 – 2000) to be 1.68 m/s at a height of 13m at their location (91.85^0 E, 21.82^0 N). But Bangladesh Centre for Advanced Studies (BCAS) finds that their measurements at a different site (91.84^0 E, 21.86^0 N) over a year lead to an annual value of 4.15 m/s at a height of 25m [1] which appears to be promising for wind electricity generation. One expects that at 50m height higher speeds may occur. The present work attempts to assess the wind resource at 50m height over the Island and predict the good locations for wind generators. For this purpose "Wind Atlas Analysis and Application Program (WAsP)", [2] developed at RISO National Laboratory, Denmark has been employed which uses time series of wind data along with information on surface characteristics of the location, obstacles due to buildings and trees close to the met station and the orography.

WAsP has been used to develop the Monthly and Annual Wind Atlas over Kutubdia at 50m height and also for four roughness conditions. A pre-feasibility analysis has been done to obtain the wind speed and power density for the four selected locations.

Wind speed data for Kutubdia

Three (3) hourly time series data of wind speed and direction for 10 years (1991 – 2000) of BMD, Kutubdia has been collected. Raw data at 10 minute intervals for the BCAS location has been collected from Sept 96 to Feb 98. Both BMD and BCAS data have been analyzed to get the diurnal, monthly and seasonal variations. It has been found that during the windy months (May to Aug) the diurnal variation in wind speed is low but for rest of the months it is high (Fig. 2). Fig. 3 shows that the monthly variation in wind speed is high for Kutubdia. As energy depends on the cube of speed, $\overline{v^3}$ therefore available energy is higher in Kutubdia than for locations having the same annual wind speed with a low speed variation. Fig. 4 shows remarkable variations in wind direction between the months of June and October at BMD, Kutubdia.

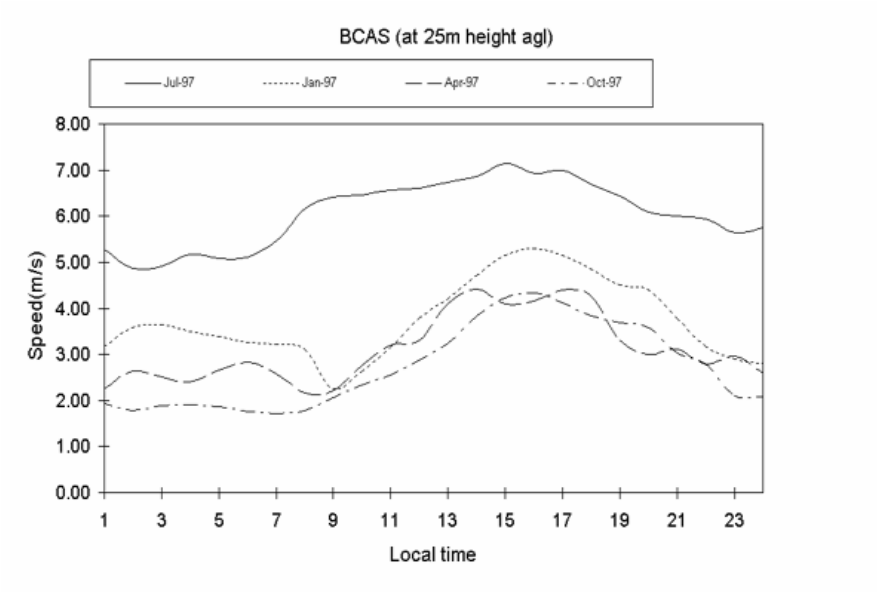

Figure 2: Hourly wind speed variation

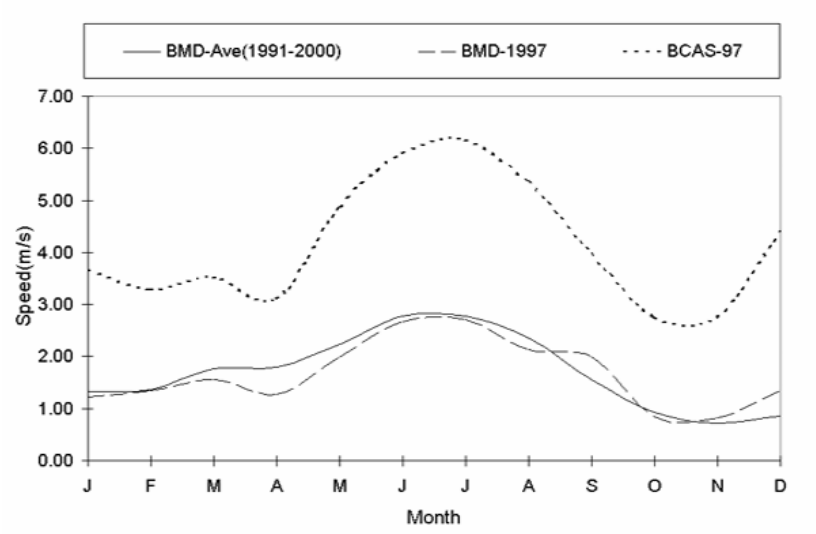

Figure 3: Monthly wind speed variation

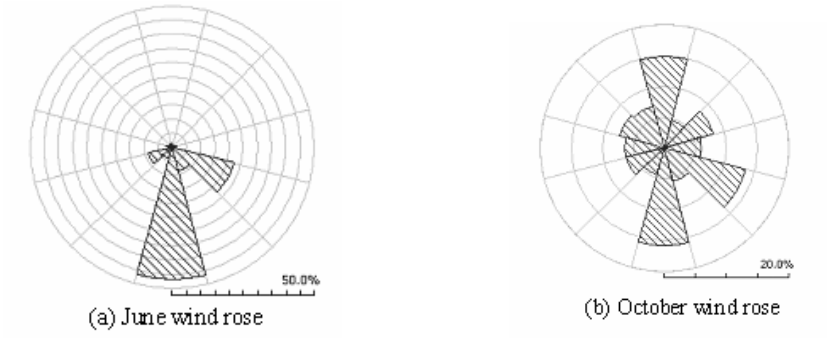

Fig. 4. Wind rose, at BMD position using 10 years data, for the months of (a) June – Average speed: 2.78m/s and (b) October – Average speed: 0.92m/s

Wind energy assessment using WAsP

WAsP is based on the physical principles of flow in the atmospheric boundary layer and takes into account the effects of different surface roughness conditions, sheltering effects due to buildings and other obstacles, and the modification of the wind imposed by the specific terrain height variations around the met station. Latitude, longitude and anemometer height are the pre-requirements to input the data for any location. Considering the effects for the obstacles, roughness and terrain the WAsP develops a wind atlas for a region around 100 km^2 in area [2].

Models for obstacles, roughness and terrain effect

In the WAsP, base map of any location is used in the MapEditor software to draw the roughness and contour lines according to the land use information and terrain description of the location. For BMD, Kutubdia, as the mast is on the roof of the met station building according to the report by Lars Landberg [3], artificial hill effect has been introduced for the met station building by modifying the ground in the WAsP by 1:5 slope[4]. In this case the anemometer height to be used should be its height from the roof. It may be mentioned that the ground elevation over Kutubdia varies from 0 – 5m only above the sea level and for the BMD station it is 3m.

Again, the BMD station is situated in an inhabited locality and the sheltering effect, due to obstructions by buildings and trees close to the met station, is to be considered. The height and depth of an obstacle, its angular position and distance from the monitoring mast and the porosity (0 – 1) have to be taken into consideration to develop the obstacle model.

Using the logarithmic wind profile, surface-layer similarity laws, geostrophic drag law and the geostrophic wind, the stability model, the roughness change model, shelter model and the orographic model from the terrain information it develops a micro-scale wind atlas/regional wind climate in the form of Weibull parameters. WAsP considers all the properties of obstacles, roughness of terrain and contour information.

Developed Wind Atlas

After analyzing all the effects the monthly and annual wind atlas over Kutubdia Island has been developed using 10 years (1991 – 2000) three hourly time series data of BMD. From the monthly wind atlas it has been found that at 50m height wind energy potentiality is fairly good for Kutubdia coast as shown in Table 1 and the annual wind atlas at different heights with roughness change has been shown in Table 2. The developed roughness model of WAsP program shows that the roughness value for coastal areas lies in between 0.001 and 0.03 m.

Table 1: Monthly prevailing wind direction, wind speed, power density (P.D) and Weibull parameters at 50m height for Kutubdia coast according to the monthly wind atlas

Month	Dir	Water Area (Roughness = 0.0002m)				Open Farmland (Roughness = 0.03m)			
		Weibull Parameter		Speed	P.D	Weibull Parameter		Speed	P.D
		A	K	m/s	w/m^2	A	K	m/s	w/m^2
Jan	N	5.5	1.53	5.0	198	4.5	1.49	4.0	110
Feb	N	5.3	1.37	4.8	212	4.2	1.33	3.9	121
Mar	S/SW	6.0	1.26	5.6	390	4.9	1.23	4.6	220
Apr	S/SW	5.4	1.08	5.3	449	4.3	0.99	4.4	308
May	S/SE	6.8	1.26	6.3	553	5.4	1.22	5.1	314
June	S	8.7	1.46	7.9	847	7.0	1.41	6.4	473
July	S	9.1	1.78	8.1	696	7.3	1.71	6.5	387
Aug	S	7.7	1.58	6.9	509	6.2	1.51	5.6	288
Sept	S	5.2	1.12	5.0	355	4.2	1.02	4.2	259
Oct	S/SE	3.3	0.97	3.4	153	2.8	0.97	2.8	090
Nov	N/NE	3.3	1.24	3.1	069	2.8	1.24	2.6	040
Dec	N	4.0	1.43	3.6	085	3.3	1.42	3.0	048
Annual		6.0	1.29	5.5	360	4.8	1.24	4.5	206

Table 2: Annual wind atlas for Kutubdia showing the predicted wind speed and power density (P.D) for four roughness classes and different heights

	Roughness class							
	(0.000 m) Water area		(0.030 m) Farmland (open)		(0.100 m) Farmland (close)		(0.400 m) Shelter belts/forest	
Height (m)	Speed (m/s)	P.D (W/m^2)	Speed (m/s)	P.D (W/m^2)	Speed (m/s)	P.D (W/m^2)	Speed (m/s)	P.D (W/m^2)
10	4.7	242	3.3	108	2.9	070	2.2	034
25	5.2	306	3.9	162	3.5	117	2.9	069
50	5.5	360	4.5	206	4.1	159	3.5	106
100	6.0	471	5.3	296	4.8	225	4.2	150
200	6.5	663	6.4	565	5.9	427	5.1	274

Predicted and measured wind speed at BCAS location

A comparative study was done between the measured values at BCAS location and the predicted values at that position from the wind atlas obtained for Sept-96 to Feb-98 period on introducing roughness, obstacle and terrain effects. It has been found that the difference between the measured and predicted monthly values were within the range of 0.01 to 0.69 m/s with a standard deviation of 0.22m/s. The prediction should become more accurate if data were available for a longer period.

Table 3: Monthly averaged BMD data and data at 25m height for the BCAS station as well as the predicted values at 25m for the same location using BMD data

Month	BMD Data (13m height)	BCAS position (25m height) Predicted value (m/s)	Measured value (m/s)	Deviation (m/s)
Sept-96,97	1.25	3.24	3.79	0.55
Oct-96,97	1.01	2.76	3.39	0.63
Nov-96,97	0.82	2.77	2.99	0.22
Dec-96,97	1.25	3.69	3.89	0.20
Jan-97,98	1.25	3.72	3.73	0.01
Feb-97,98	1.22	3.39	3.11	-0.28
Mar-97	1.56	4.06	3.53	-0.53
Apr-97	1.27	3.26	3.11	-0.15
May-97	2.15	5.08	4.89	-0.19
Jun-97	2.67	5.67	5.90	0.23
Jul-97	2.70	5.76	6.17	0.41
Aug-97	2.13	4.65	5.34	0.69
Ave	1.61	4.00	4.15	0.22 (S.D)

Selection of good locations – Wind resource map for Kutubdia

The developed wind atlas, shown in Tables 1 and 2, were used to find out high wind speed locations at a height of 50m by generating the wind resource map (figure 6) with the help of (100 x 100) m^2 grid cells. From this resource map the wind speed and power density obtained for four good locations have been shown in Table 4. Fig. 7 presents the four selected locations, BMD and BCAS stations positions along with information on roughness and terrain.

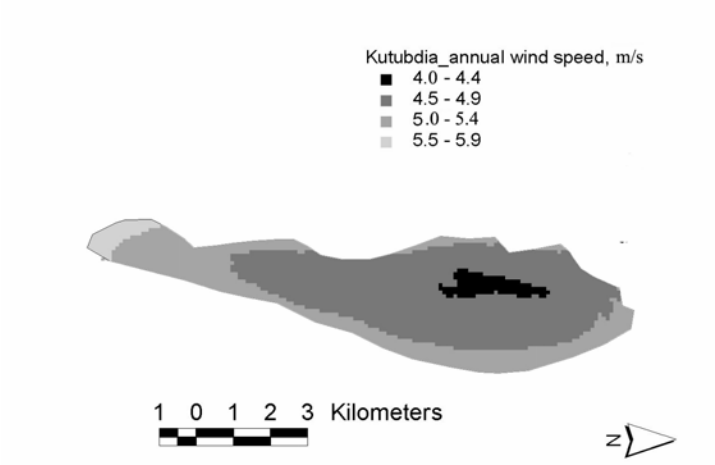

Fig. 6. Wind resource at 50m height above the ground level for Kutubdia Island

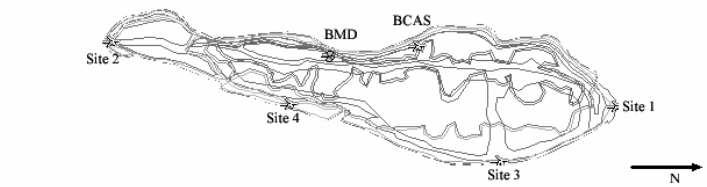

Fig. 7. Map of Kutubdia, showing the four selected locations along with BMD and BCAS stations, roughness (double line) and contour (single line) are also shown

Table 4: Predicted speed and power density (P.D) for BCAS and four other locations in Kutubdia at 50m height

	Wind Speed and Power Density (PD) At 50m height									
	BCAS		Site1		Site2		Site3		Site4	
Month	Speed (m/s)	P.D (w/m^2)	Speed (m/s)	P.D (w/m^2)	Speed (m/s)	P.D (w/m^2)	Speed (m/s)	P.D (w/m^2)	Speed (m/s)	P.D (w/m^2)
Jan	4.44	149	4.95	198	4.66	164	4.80	175	4.29	120
Feb	4.39	165	4.70	194	4.61	188	4.58	184	4.28	148
Mar	5.17	302	5.15	274	5.53	380	5.31	341	5.26	346
Apr	4.92	355	4.84	365	5.24	444	4.97	406	5.01	402
May	5.79	442	5.66	427	6.28	551	6.01	474	6.08	491
Jun	7.06	628	6.99	610	7.85	843	7.64	777	7.72	802
Jul	7.25	501	7.08	477	8.05	694	7.85	655	7.94	674
Aug	6.22	369	6.03	334	6.89	507	6.73	480	6.80	495
Sep	4.60	288	4.55	298	5.00	353	4.86	320	4.88	324
Oct	3.06	106	3.19	118	3.30	149	3.28	144	3.17	141
Nov	2.81	052	3.05	063	2.99	062	3.02	062	2.81	050
Dec	3.24	063	3.60	084	3.41	071	3.51	076	3.17	053
Annual	5.03	273	5.08	270	5.44	353	5.31	324	5.23	322

Predictions using Cox's Bazar data

The annual wind atlas of BMD, Cox's Bazar, which is 40km away from Kutubdia in the south-east direction, has been developed from 10 years (1991 – 2000) three hourly time series data to have a second estimate of the wind climate of Kutubdia. Maheshkhali, another Island with hillocks, is situated in between Cox's Bazar and Kutubdia. It may affect the wind climate of Kutubdia during monsoon period when south / south-east wind flows towards Kutubdia and may also affect the wind climate of Cox's Bazar during off-monsoon period when wind flows from the north / north-east direction towards the Cox's Bazar. Computations show that the difference between the predicted annual wind speeds using Cox's Bazar and Kutubdia Wind Atlas for all the sites is within 0.5 to 0.6 m/s at a height of 50m. The agreement should be considered to be satisfactory.

It appears that the Southern and Eastern parts of Kutubdia are better then other parts for wind generators. For November and December the wind speed and the power density are low (Table 1, 4) and hybrid generation using diesel or preferably PV would be required for supplying adequate power throughout the year.

Annual Energy Production

The amount of electricity that can be generated by the wind depends on wind turbines as well as wind speeds. The electricity generation has been analyzed for a few wind turbines of different capacities, hub heights and rotor diameters. Table 5 shows the Monthly Energy Production (MEP) in MWh at site 2 using the power curves of 3 turbines from the manufacturers and WAsP software. For other sites MEP should be marginally lower as the wind speed is slightly low.

Table 5: Monthly and Annual energy production for three turbines at site 2

Month	Vestas V44 (600kw) Hub height: 40.5m Rotor dia: 44m		NEG-Micon 600/43(600kw) Hub height: 45m Rotor dia:43m		Nordex N43 (600kw) Hub height: 50m Rotor dia:43m	
	Speed (m/s)	MEP (MWh)	Speed (m/s)	MEP (MWh)	Speed (m/s)	MEP (MWh)
Jan	4.50	054	4.58	050	4.66	060
Feb	4.47	057	4.54	053	4.61	063
Mar	5.40	087	5.46	082	5.53	092
Apr	5.13	080	5.19	076	5.24	085
May	6.15	107	6.21	101	6.28	112
June	7.70	150	7.78	144	7.85	158
July	7.89	163	7.97	155	8.05	170
Aug	6.75	125	6.82	119	6.89	132
Sept	4.90	074	4.95	070	5.00	079
Oct	3.22	036	3.26	033	3.30	039
Nov	2.91	020	2.95	018	2.99	023
Dec	3.30	023	3.36	021	3.41	028
Annual	5.19	976	5.26	922	5.32	1041

Conclusion

The computed wind speed of BCAS location at 25m height from BMD data at 13m height has been found to be close to the measured values. This validates the WAsP technique employed. Hence the estimations shown in Table 4 should be dependable. However the wind speed varies from year to year and measurements at 50m height at selected locations would be welcome. If sheltering effect is present the speed would be lowered and sites without serious obstacles may be selected for wind generators. This study and analysis provides assessment of wind energy over Kutubdia Island. From table 5 it may be concluded that wind electricity generation should be feasible in the island. PV/Diesel back up may be needed for Oct – Dec when the wind speed is low.

Acknowledgement

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References

1. Eusuf M., 1998, "Bangladesh Centre for Advanced Studies, Wind Energy Study (WEST) Project", Final Report, Bangladesh.

2. Troen I. and E. L. Petersen, 1989, European Wind Atlas, Risoe National Laboratory, Denmark.

3. Lars Landberg, 2000, The mast on the House, *Wind Energy* 3.

4. Khadem S. K, J. Badger, S. M. Ullah, S. K. Aditya, H. R. Ghosh and M. Hussain, 2003**,** *The effect of obstacles close to the anemometer mast located on a building on wind flow in the WAsP model,* RETRUD-03 Conference, Kathmandu, Nepal.