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EXPLORING WIND ENERGY POTENTIAL IN KPK-PAKISTAN BY USING MULTI CRITERIA APPROACH

Lubna RAFIQ[1], Sapna TAJBAR[2,*]

[1]Geoinformation, University of Salzburg, Austria
[2]Department of Physics, Shaheed Benazir Bhutto Women University, Peshawar, Pakistan

ABSTRACT

Renewable energy resources have great potential to give solution to the long-lasting energy deficiency problems being faced by Pakistan. The aim of this study was to make use of multi criteria analysis for the identification of wind potential sites in KPK, Pakistan by utilizing the monthly 10 years (1983-1993) and 22 years (1983-2005) annual average wind speed data sets for the six districts (Chitral, Peshawar, Dir, DIK, Buner and Mansehra) at 10m and 50m, 100m, 150m, 300m altitudes, Earth Skin Temperature (^{0}C) and Atmospheric Pressure (kpa) respectively. At 10 m altitude, annual wind speed analysis showed similar pattern among all the districts, each with two maximum peaks one in April and the other between October and November. Multi-criteria Approach involved, creating suitable criteria for selected variables then classification (based on each variable magnitude), scores were then assigned to each class. Based on methodology (MCA) applied in this research, Chitral district appeared as the best location for exploiting in terms of wind power.

Keywords: Wind Potential Site-Wind Speed, Earth Skin Temperature, Atmospheric Pressure, Multi Criteria Approach, KPK-Pakistan

1. INTRODUCTION

Energy plays a key role in the development of a country's economy [1, 2]. It is considered to be a vital constituent for all the activities of humans and gives its services for lighting homes, transportation, extraction of minerals, health and manufacturing things in industries. Worldwide there is an energy crisis due to the immense rise in energy consumption coupled with the fossil fuel depletion. Pakistan is also facing problems because of insufficient energy to meet the needs of the country. It has relied only on non-renewable energy resources such as fossil fuels (coal, oil and natural gas) which release harmful gases in the environment, therefore contribute towards the global warming and are not sufficient to overcome the energy deficiency [3]. There is general awakening to avoid the pollutant energy resources; Pakistan should pay attention towards its abundant renewable energy resources such as wind, solar, hydropower, biomass and geothermal resources. Among these renewable energy resources, wind energy is the most promising, sustainable and commercially appealing source of energy for the generation of electricity because of its significance due to low CO_2 emissions and fastest growth around the world [4-6]. The energy from wind is produced in over 75 countries around the world out of which 21 countries have above 1000 MW of installed capacity. Over 40 GW added in 2011 which increased the world's total installed capacity to 238 GW. The wind speed so far observed in Pakistan is from 7-8 m/s which are the most exploitable and suitable wind speeds [7]. Pakistan is the prospective site for wind energy of around 300,000 MW in the country according to the map prepared by NREL (National Renewable Energy Laboratory) with the help of AEDB (Alternative Energy Development Board) and USAID (United States Agency for International Development) [8]. Therefore considering the potential importance of wind energy, globally many studies have been conducted using the satellite based data [5, 9, 10, 1]. However, such studies over Pakistan (study area) are scant. Therefore it is the first time to use the NASA Surface meteorology and Solar Energy (SSE) datasets to identify the areas for wind energy potential in KPK, Pakistan by using the multi criteria analysis. Worldwide different methods are used for the determination of wind energy potential.

*Corresponding Author: sapnatajbar@gmail.com
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According to a study carried out for India to determine the feasibility of wind power in the region and to measure the available offshore potential of wind, at turbine hub height of 80m wind maps were created by the usage of Geographic Information System (GIS) [33]. A study carried out in Pakistan, contour maps were drawn for the months of winter and summer i.e. January and July, as well as annual average values of wind speed [34]. In a study for the Ahmadabad, India Weibull distribution was used for the wind climate modelling and to determine properly the potential of wind energy [35]. A case study for the Kujawsko-Pomorskie Voivodeship also made use of GIS for the evaluation of wind energy potential [36]. In a study for the Germany, actual high-frequency production data in a five parameter logistic function was used for finding the relation between wind data and energy generation. The wind energy index resulted allowed a turbine-specific assessment of the anticipated wind power at a location which is unobserved [37].

The structure of this paper is as follows. Section 2.1 comprises a general description of the study area where as section 2.2 describe the data used and description and section 2.3 presents the methodology adopted for this study, while section 3 presents results and discussion followed by some conclusions in section 4.

2. STUDY AREA, DATA USED, GENERAL DESCRIPTION AND METHODOLOGY

2.1. Study Area

Khyber Pakhtunkhwa (30º-35ºN & 67º-72ºE), one of the five provinces of Pakistan is located on the Iranian plateau and Eurasian land plate with an area of 74, 521 km^2. Geographically, it splits into two zones with northern one from Hindu Kush to Peshawar and southern one from Peshawar to Derajat basin. The climate of KPK changes from extremely cold (such as Chitral) to extremely hot (such as Dera Ismail Khan) areas. On availability of required data sets only six districts (Figure 1) of KPK (Peshawar, Dir, Chitral, DIK, Buner and Mansehra) were selected for this study. Chitral district temperature alters from 30ºC (86ºF) to 0ºC (32ºF) in the months of July and January respectively. The temperature of Buner varies from 44ºC during the summer season to -2ºC during the winter season. Peshawar climate is semi-arid with intense hot summers (40ºC) and mild winters (18ºC). DIK has usually extremely hot and dry summers with low rainfall in the region. Dir district climate is intensively humid subtropical and it has a very penetrative monsoonal periods along with the heavy thunderstorms. The Mansehra district of KPK climate is warm in summer and cold in winter with temperature ranges from 2ºC to 36ºC [11].

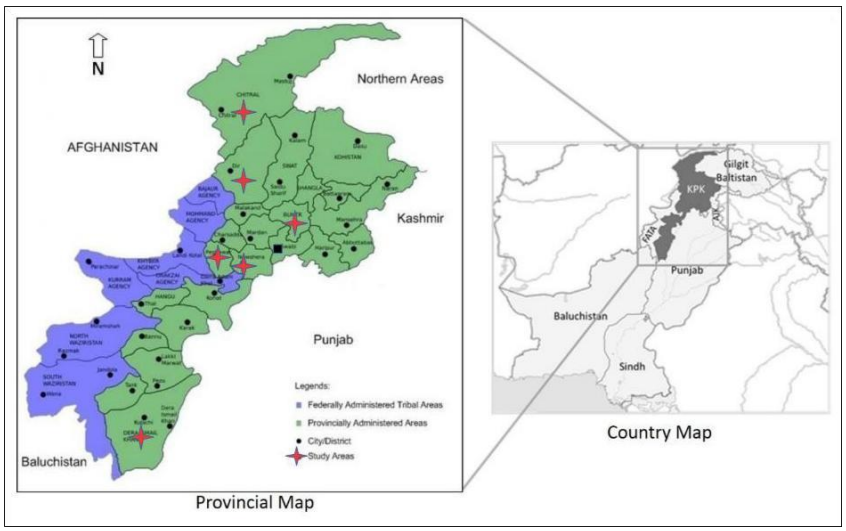

Figure 1. Study Area

2.2. Data Used and Data Description

2.2.1. Surface meteorology and Solar Energy

Surface meteorology and Solar Energy (SSE) is a renewable energy resource website which is sponsored by the NASA's Applied Science Program in the Science Mission Directorate developed by Power (Prediction of Worldwide Energy Resource Project). It contains over 200 satellite-acquired meteorology and solar energy parameters with monthly average from 22 years of data and data tables for a specific site [12]. Data sets from SSE-NASA are continuous and stable 10-year world's climatology of insolation and meteorology data on a 1^o x 1^o grid system. The SSE data sets are not for the purpose of replacing the ground measurement data but are to fill the space where the ground data are not present [13]. The original SSE data-conveyance website, is intended to supply an easiest way to obtain the parameters required in the renewable energy industry (such as solar and wind energy) [14]. Table 1 contains the data sets (such as wind speed at different heights, average earth skin temperature and atmospheric pressure) obtained from the SSE website.

Table 1. List of parameters with corresponding data source used in study

Data Source	Parameters	Temporal Resolution	Spatial Resolution	Pressure Levels (meters)	Period Covered
SSE NASA	Wind speed (m/s)	Daily	1^ox1^o	10 50, 100, 150, 300	1983-1993 1983-2005
	Average Earth Skin Temperature (^{o}C)	Daily	1^ox1^o	Surface	1983-2005
	Atmospheric Pressure (kpa)	Daily	1^ox1^o	Surface	1983-2005

2.3. Methodology

The study aims to utilize free of cost satellite derived data sets for the identification of best sites possessing maximum wind energy potential within study area. The methodology adopted for this study is briefly described as follows;

2.3.1. Long Term Temporal Wind Pattern

Wind speed historical data (daily) of 22 years (i.e. 1983-2005) at 50m, 100m, 150m and 300m from surface for 06 districts were acquired from SSE. Monthly averages for corresponding altitudes were calculated (Table. 2) and then mapped, whereas wind speed at 10m above surface from SSE-NASA was available only for 10 years.

Table 2. 22 Years Average wind speed at different altitudes

Study Area (Districts)		Avg. Wind speed (at 50m) m/s	Avg. Wind speed (at 100m) m/s	Avg. Wind speed (at 150m) m/s	Avg. Wind speed (at 300m) m/s
1.	Chitral	6.97	7.73	8.22	9.12
2.	Peshawar	6.34	7.03	7.47	8.29
3.	Dir	6.8	7.54	8.02	8.9
4.	DIK	4.81	5.34	5.67	6.3
5.	Buner	5.69	6.31	6.71	7.44
6.	Mansehra	6.3	6.99	7.43	8.24

2.3.2. Multi Criteria Analysis (MCA)

Traditional single criteria assessment approaches can no longer handle the complexity of the system [15] and therefore not suitable approach for such problem considering in this study, whereas multi-criteria assessment methods (MCAM) provide a simple and flexible criteria [16] to handle and bring together a

wide range of variables in different ways and thus offer useful alternative and hence provide solution of the problem.

MCA performed via the following procedure;

- Classification (based on corresponding variable`s magnitude)
- Scores were then assigned to each class accordingly
- Identification of best location (district) with maximum total score

Table 3. Multi Criteria Analysis: Identified Criteria for selected variables

	Category/Variables	Altitude (m)	Method	Ideal Condition
1.	Wind Speed (m/s)	10, 50, 100, 150, 300	Classification	High wind speed (class)
2.	Average Earth Skin Temp. (°C)	Surface	Std. Dev/Classification	Low variation
3.	Atmospheric Pressure (kpa)	Surface	Std. Dev/Classification	Low variation

Table 3 shows the multi criteria analysis for the selected variables. Based on the variables magnitudes, three classes were made (such as lowest class, middle class and highest class) and scores were assigned to lowest class as 1, middle class as 2 and highest class as 3. For the wind speed, the highest class was considered as the ideal condition and for the earth skin temperature as well as atmospheric pressure the lowest class is an ideal condition. All the scores for each district were added and the district with maximum total score was identified as the ideal location.

3. RESULTS AND DISCUSSION

Wind energy is the clean (environment friendly), sustainable and inexhaustible energy resource [17-21]. In order to initiate the wind farms at a large scale, long term comprehensive apprehension of the potential sites is needed for the progression of this energy resource. Pakistan having the indigenous amount of wind energy resources is therefore suitable for the harvesting and progress of wind energy. The goal of this study was to identify the wind potential sites in KPK; Pakistan using the multi criteria based approach. Results from this study are briefly explained below;

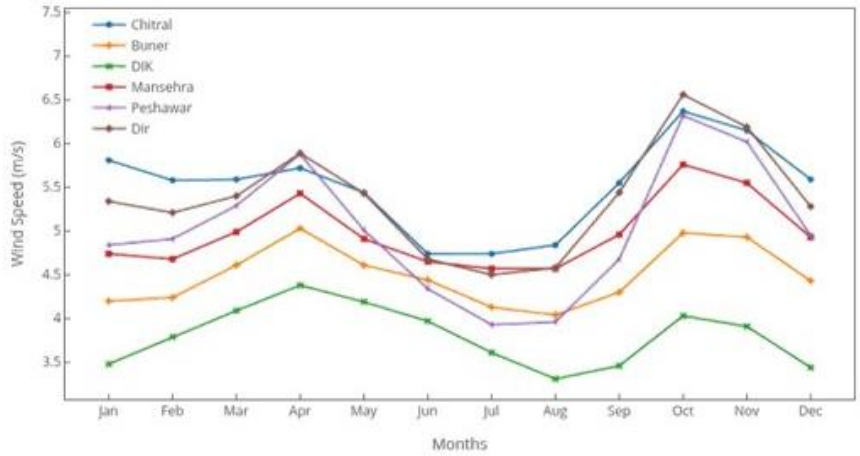

Figure 2. Avg. (10 yrs) Monthly Wind Speed at 10m above surface (data source: SSE-NASA)

Figure 2 depicts the 10 years (i.e. 1983-1993) monthly average wind speed at height 10m. All the districts showed similar patterns with two maximum peaks one in April and the other peak between October and November. It should be noted that Chitral and Dir districts shows significant high wind speed all over the years as compared to the other districts.

Similar results have been discussed for different countries [22-27].

3.2. Multi Criteria Analysis

Globally many studies have been carried out using the multi criteria analysis for the selection of suitable wind potential sites [28-32]. In this study Multi Criteria analysis is applied for each district individually. As shown in table 3, parameters selected for MCA are distributed in three categories. Category 1 comprises parameter Wind Speed: Monthly averages of wind speed at altitudes 10, 50, 100, 150 and 300 m above from surface are classified and scores are assigned to each class (as shown in Table 4). Category 2 comprises parameter Skin Temperature: Standard deviation of Skin Temperature and then classified and score are then assigned accordingly. Category 3 comprises parameter Atmospheric Pressure (surface). Standard deviation of Atm. Pressure and then classified and scores are then assigned to each class. Low variation (std. deviation) in variables comprised in category 3 & 4 are good indicator for stable environment/system at given location. Stable system is the main factor required for wind turbine`s high efficiency. As shown in table 5, based on the total score of each district, Chitral district is identified with maximum total score followed by district Dir where as district DIK found with minimum total score.

Table 4. Classification criteria for Monthly Wind Speed (m/s), will be used as input for MCA

10 Yr Average WS (m/s)						
	Chitral	**Peshawar**	**Buner**	**DIK**	**Dir**	**Mansehra**
January	5.81	4.84	4.20	3.48	5.34	4.74
February	5.58	4.91	4.24	3.79	5.21	4.68
March	5.59	5.29	4.61	4.09	5.40	4.99
April	5.72	5.88	5.03	4.38	5.89	5.43
May	5.44	5.01	4.61	4.19	5.43	4.91
June	4.74	4.34	4.44	3.97	4.68	4.65
July	4.74	3.93	4.13	3.61	4.50	4.57
August	4.84	3.96	4.04	3.31	4.58	4.57
September	5.55	4.68	4.30	3.46	5.44	4.96
October	6.37	6.32	4.98	4.03	6.56	5.76
November	6.15	6.02	4.93	3.91	6.19	5.55
December	5.59	4.95	4.43	3.44	5.28	4.93
Annual Average	5.50	5.01	4.49	3.80	5.37	4.97
Classification of data according to the following criteria:						
Mini	3.31					
Max	6.56					
Classes (3)	(Max-Mini)/3	1.0833333				
Class 1	Mini+1.08333	4.3933333	(Lowest Class) 3.31 to 4.3933333			
Class 2	Class 1+1.083	5.4766667	(Middle Class) 4.3933333 to 5.4766667			
Class 3	Class 2+1.083	6.56	(Highest Class) 5.4766667 to 6.56			

Table 5. Final scores of selected districts calculated by using MCA

Months/Total score	**Chitral**	**Peshawar**	**Buner**	**DIK**	**Dir**	**Mansehra**
January	15	10	5	5	10	10
February	15	10	5	5	10	10
March	15	10	10	5	10	10
April	15	15	10	5	15	10
May	10	10	10	5	10	10
June	10	5	10	5	10	10
July	10	5	5	5	10	10
August	10	5	5	5	10	10
September	15	10	5	5	10	10
October	15	15	10	5	15	15
November	15	15	10	5	15	15
December	15	10	10	5	10	10
Total Scores	160	120	95	60	135	130

4. CONCLUSIONS

In spite of having vast potential of energy resources, Pakistan is still an energy deficient country and has only depended on its fossil fuels for the fulfillment of its energy demand. The impetus of this study was to make use of multi criteria analysis for the identification of wind potential sites in KPK, Pakistan by analyzing the monthly 10 years (1983-1993) and 22 years (1983-2005) annual average wind speeds for the six districts at 10m and 50m, 100m, 150m, 300m altitudes respectively. At 10m altitude the result showed that all the districts represented similar pattern with two maximum peaks one in April and the other between October and November. 22 years (i.e. 1983-2005) average wind speed at different altitudes (50m, 100m,150m, 300m) showed that **a**mong all the districts, Chitral and Dir districts were identified with the maximum wind speed at each altitude. Based on the multi criteria analysis, Chitral district was identified with maximum total score. It can be concluded that based on methodology applied in this research, Chitral district appeared as the best location for exploiting in terms of wind power.

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