Satellite Image Identification of Wind Channels to Delineate Wind Energy Generation Sites in Pakistan

Zeeshan Alam Nayyar[a,*] and Nayyer Alam Zaigham[b]

[a]New Technologies Research Group, Department of Applied Physics, University of Karachi, Pakistan

[b]Unit for Ain Zubaida & Groundwater Research, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract: Technologically, all the renewable energy sources are viable and consequently suit to efforts for poverty alleviation and cleaner environment in Pakistan. They can play an important role in meeting the challenge of providing future electricity to all parts of the country. Wind energy is one of these renewable sources. Considering the geological & geomorphologic setup, geographical position and climatic cycles, Pakistan has tremendous wind potential. Pakistan has about 1000 km long coastline, which could be utilized for the installation of wind farms and wind-monitoring stations as well. Various preliminary comparative studies apparently show that the wind potential is not uniformly distributed along the coastal belt of Pakistan. The present research study is based on the analyses of the satellite images of different periods. On the bases of the result of the study, the prospective wind channels have been identified all along the coastal belt of Pakistan, which are the ideal regions to establish the wind farms for the generation of electricity on the commercial scale.

Keywords: Wind Energy, Wind Channels, Satellite Images, Energy Generation, Pakistan.

1. INTRODUCTION

Pakistan stretches from 24°N to 37°N latitudes and from 61°E to 78°E longitudes. The total land area of Pakistan is about 800,000 square kilometers (Figure **1**). The conventional energy sources, i.e. fossil fuels (such as coal and petroleum and biofuels like wood), mega-hydels, and nuclear plants have remained the main energy sources of choice of the world for centuries. Now, there has been a growing recognition, for more than one reason, of the dangers inherent in continuing with the model of economic development based on these sources, particularly the excessive consumption of fossil fuels. One reason is that the reserves of fossil fuels are not unlimited and at the present rate of consumption they would not last very long.

According to a research report [1] based on Ministry of Petroleum and Natural Resources' information, Pakistan will be going to suffer energy crisis from 2014 because 10 of largest oil and natural gas reservoirs of the country will be exhausted during 2014 to 2025, includes Sui, Mari, Qadirpur, Bhat and Zamzama for the natural gas and Pandori, Adhi, Kanar, Zoor and Dhodhak for oil (Figure **2**). Pakistan is producing 3,549 million cubic feet natural gas daily out of which 61.8 percent (2,194.8 million cubic feet) is acquires from the five main gas fields. Right now the total oil production of the country is about 58,805 barrels daily and 36.8 percent (21,615 barrels daily) out of it is produced by these five main fields.

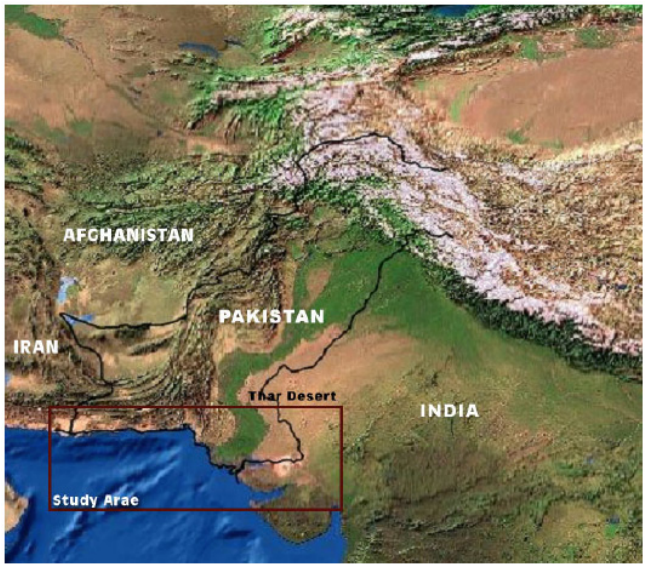

Figure 1: Map shows the study area and the geomorphological features of Pakistan.

Yet another aspect that has come into sharp focus is that the developing countries can ill afford to depend excessively upon petroleum imports marked as they are by volatile price fluctuations. Moreover, indiscriminate use of fuel wood leads to deforestation with consequent environmental hazards and inefficient burning of fuel wood leads to an increase in indoor air pollution and consequent health hazards especially for women and children. Similarly, the other conventional sources of energy generation have their adverse impacts on environment [2-4].

Efforts have also been made to exploit the existing conventional energy resources to build a strong

*Address correspondence to this author at the New Technologies Research Group, Department of Applied Physics, University of Karachi, Pakistan; Tel: +92 321 2812007; E-mail: zanayyer@uok.edu.pk; life9to5@yahoo.com

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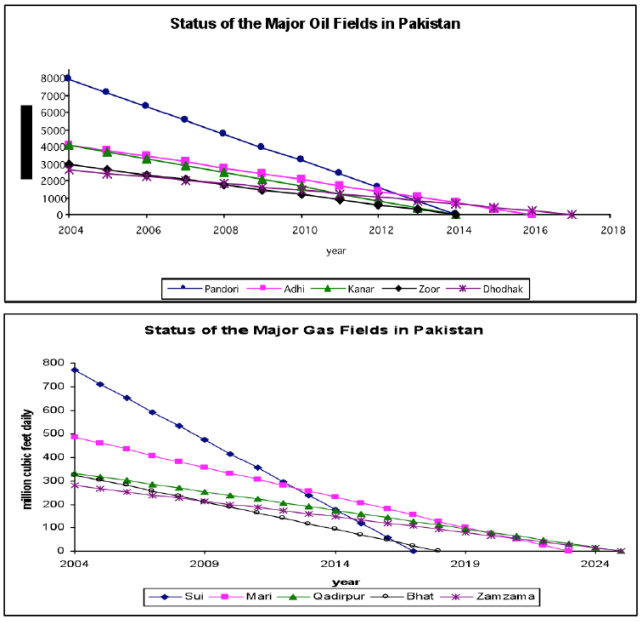

Figure 2: Current status of the oil and gas fields' situation showing the depletion rate of major field. Source of Data: [1].

indigenous exploration and production base. In spite of all these efforts, the achieved results so far are not cost effective, not helpful in reduction of import dependence, fail to promote self-reliance through accelerated exploitation of conventional energy resources with minimum environmental degradation [5, 6]. Though the thermal power generating capacity has increased rapidly during last few years due to foreign investment in Independent Power Producers [7-10], but at the same time, it has caused increased air pollution and GHG emissions with the result of degradation of health and eco-systems.

Therefore, the development of the renewable energy sources can play an important role in meeting these challenges. Technologically, all the renewable energy sources are viable and consequently suit to efforts for poverty alleviation and cleaner environment in Pakistan. Considering the geological & geomorphologic setup, geographical position and climatic cycles, Pakistan has tremendous wind potential. Pakistan has 1000 km long coastline, which could be utilized for the installation of wind farms [11]. At present, the facilities for generating electricity from wind are virtually nonexistent in the country. As of today, we have no significant wind energy generation project, most probably because the preliminary wind power potential of Pakistan has not been adequately worked out [12]. Various preliminary comparative studies show that the wind potential is not uniformly distributed along the coastal belt of Pakistan, which seems not to be true as a whole.

This paper describes the identification and role of wind channels and the delineation of the prospective areas of the coastal belt of Pakistan based on the critical analyses of the satellite data and the imageries.

2. IDENTIFICATION & IMPACT OF WIND CHANNELS

During 2001-2002, through the local NGOs the Empower of New Zealand conducted the feasibility studies under the funding of New Zealand Official Development Assistance (NZODA) for the estimation of site-specific wind potential at Chib-Kalmati village of the Gwadar coastal area and in Zardaloo valley of Sibbi district in central Balochistan province. A 20m high wind mast was installed to gather wind speed and directional data. The collected data show that the wind resource at the specific site in Gwadar area was indeed strong, but only for short periods each day. On the other hand, the central Balochistan offered relatively lower peak wind speeds but more consistent wind resources throughout the day as evident from the graph (Figure **3**) illustrating a wind data comparison of both sites. This caused some considerable surprise locally and it was not readily accepted in some quarters but the data collected was unambiguous for these locations. Wind resources in Sibi were found to offer a better power generating resource than those in the coastal site in Gwadar area. The general assumption widely held in Pakistan was and still is that the Makran coastal region of Balochistan Province held the best wind resources than the central inland areas, but the results are found the opposite to be true [13].

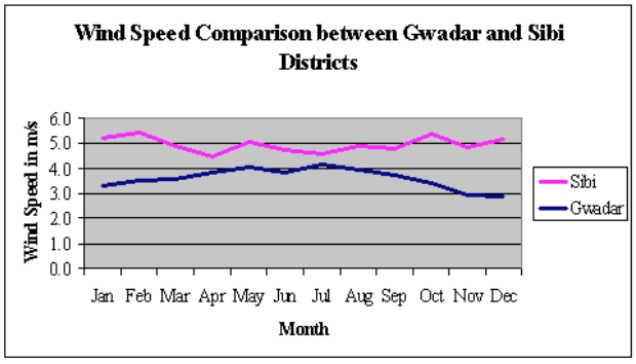

Figure 3: Wind speed correlation between local sites of Gwadar (Coastal location) and Sibi (inland location) districts in Balochistan province. Source: [13].

In fact, on the results of this one site-specific wind study at lower altitude (20 m), the whole Balochistan coastal area cannot be rejected. The results of an integrated study based on the satellite images and climatic data (particularly the wind data) show

interesting pattern of wind distribution along the coastal belt of the Balochistan province. The detailed research study is in progress presently, but the preliminary results of this study show that the wind blows in north-south oriented channels, which can be identified based on the comparative study of satellite images. Satellite images from various sources/sensors including NASA's MODIS, NOAA's AVHRR, SeaWIFS and Meteosat-5 have been acquired for the period of 5 years i.e. 2001 to 2004 [14-18].

Different analyses have been performed to enhance the dust storms encapsulating the study area. For the NOAA AVHRR images, both Visible and IR window channels have been analyzed. Dust on the ground can be detected *via* IR window images because of the temperature difference and the dust over the ocean can be identified by Visible window images because the temperature contrast between water and dust reduces and it cannot be seen by IR window images. SeaWIFS images have the advantage of high spatial resolution of about 1 km. The false-color composite images of SeaWIFS use three channels; the 670 nm as red, 555 nm as green and 412 nm as blue. For example, a false-color satellite image from SeaWIFS have been processed (Figure **4**) and this image reveal how the wind plumes originate from wind scouring over small, dry lake beds in Afghanistan and spread over the Arabian Sea covering the western Makran coast. Unlike multispectral satellites like AVHRR and SeaWIFS, Meteosat has only two channels that show dust well: visible and longwave infrared. The Meteosat-5 visible images give us dust patterns over the ocean, while the combine (both the visible and the infrared) color images from Meteosat gave us more comprehensive result and eliminate the need to switch between visible and infrared images.

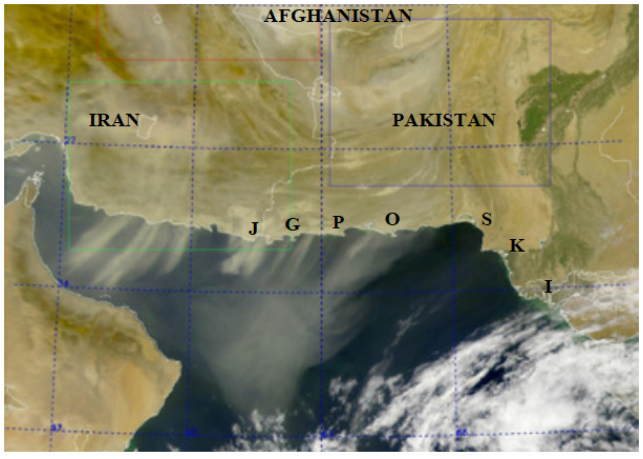

Figure 4: On October 10, 2001, dust storm originating from the Afghanistan covering the western Makran coast (I=Indus Delta, K=Karachi, S=Sonmiani, O=Ormara, P=Pasni, G=Gwadar, J=Jiwani)**.** Satellite image source: [17].

Finally we have performed satellite image processing on the NASA MODIS products acquired by the NASA's Terra satellite Moderate Resolution Imaging Spectroradiometer (MODIS). The true-color satellite scene (Figure **5**) shows strong winds blowing dust and sand from the Makran Mountains in southwestern Pakistan and Iran out over the Arabian

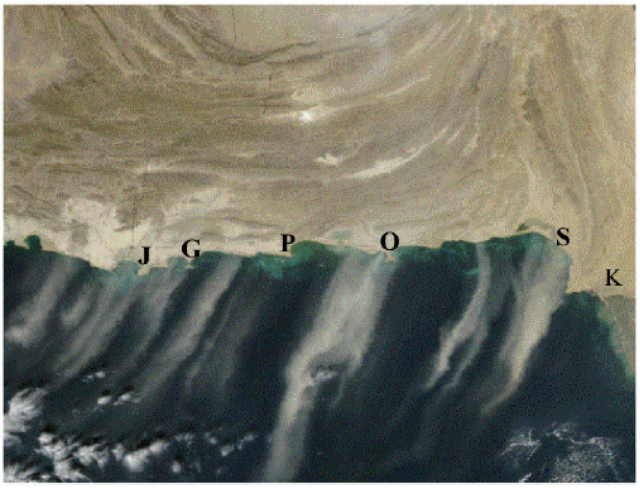

Figure 5: In early December 2003, strong winds were blowing dust and sand from the Makran Mountains in southwestern Pakistan and Iran out over the Arabian Sea, which have revealed the locations of the wind channels along the Balochistan coastal belt (K=Karachi, S=Sonmiani, O=Ormara, P=Pasni, G=Gwadar, J=Jiwani)**.** Satellite image source: [15].

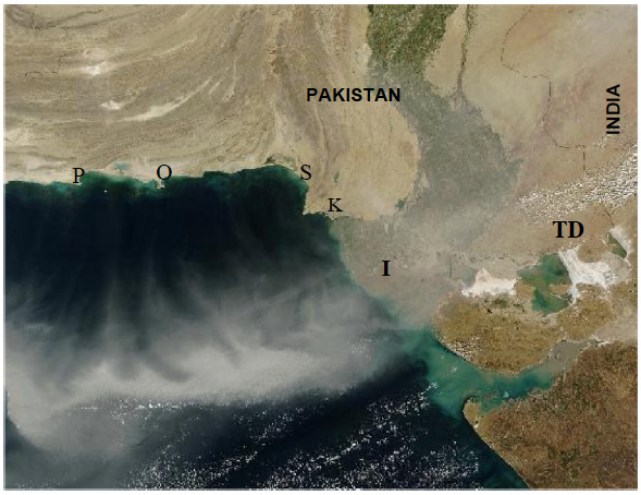

Figure 6: The true-color satellite scene shows a dust storm blowing along Pakistan's southeastern coast and out over the Arabian Sea revealing the NE-SW oriented wind channel passing across the southern Sindh province on February 9, 2004 (TD= Thar Desert, I=Indus Delta, K=Karachi, S=Sonmiani, O=Ormara, P=Pasni)**.** Satellite image source: [15].

Sea. The wind channels are evidently revealed due to the presence of dust demarcating the prospective areas for the detailed inland wind measurements to study the wind consistency and potentiality for the development of commercial wind farms all along the Balochistan coastal area. Apparently, the areas from western part of Karachi to Sonmiani extending westward up to eastern part of Hingol, Ormara, the area between Pasni and Gwadar, and the area between western part of Gwadar and Jiwani, seem to hold high wind potential.

Similarly, another satellite image (Figure **6**) from MODIS shows the dust blowing along Pakistan's southeastern coast and out over the Arabian Sea. The northeast-southwest oriented significantly wide wind channel is clearly revealed showing the existence of high wind potential. This wind channel passes across the coastal-deltaic region and the Thar Desertic areas of southeastern Sindh province. This wind channel seems to extend up to Rajasthan area of India.

During the present study, these satellite imageries of different periods revel that the trend of dust storm varies from region to region in the coastal areas of Pakistan In Balochistan coastal area, the speed of the dust storm is strong and moreover the dust storm carries coarser sediments, which can create enormous abrasion, attrition and other physical & mechanical damages. On the other hand, in Sindh coastal area the dust storms are relatively of low speed and carry finer sediments. Such finer dust can in-house and stick the sensitive parts of the wind turbines and other relevant mechanical devices reducing their life, if adequate system is not selected for the installation under specific prevailing atmospheric environment.

In areas covered by these satellite images, no detailed wind mapping has been done at the appropriate altitudes, i.e. 50 m and above, which is imperative for the successful development of the commercial wind farms. Furthermore, the impact of natural hazards like dust-storms should also monitor on regular basis to improve the technology and its outcome.

Based on the 50 m wind data acquired by the NASA's Goddard Earth Observing System - Version 1 (GEOS-1), another study is in progress. The study area is spread from 22°N to 27°N and 61°E to 73°E (Figure **1**). The results of the initial plots of 10-years averages of the wind velocity data of the Arabian Sea and the coastal belt of Pakistan (Figure **7**) show the presence

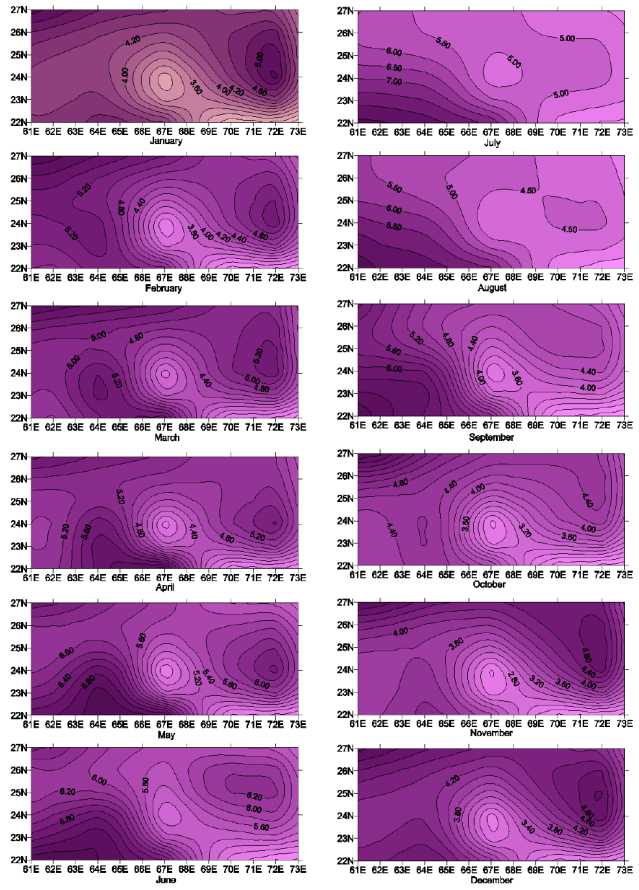

Figure 7: Plots of Wind speed at 50m (m/s) – 10-years monthly averages. Data accuracy is 1.3 m/s (-0.2m/s). See Figure **1** for location of study area. Source of data: NASA GEOS-I.

of high wind potential throughout the year except a period from September to December. Since the satellite data is of reconnoitry nature, a realistic wind model can only be achieved through detailed inland wind mapping, which is expected to be more prospective.

3. CONCLUSION

The present study only covers the coastal areas of Pakistan, which shows bright wind potentials to undertake feasibility studies for the development of the commercial wind energy generation facilities. The climatic conditions and the geomorphological set ups throughout the country are witness for the presence of the high wind potentials in other parts of Pakistan.

The present study shows that the prospective sites can be identified by utilizing satellite technology for more detailed site-specific wind study in the areas having relatively good winds rather than the whole coastal belt of Pakistan.

The areas from western part of Karachi to Sonmiani extending westward up to eastern part of Hingol, Ormara, the area between Pasni and Gwadar, the area between western part of Gwadar and Jiwani, the coastal-deltaic region and the Thar Desertic areas of southeastern Sindh province have been identified for detailed wind potential study.

The impact of the dust-storms on the development of wind energy technology should also consider seriously taking maximum benefit.

REFERENCES

[1] Tariq N. Energy crisis of Pakistan: Report of Jang Development Reporting Cell. Karachi: The Daily Jang 2004.

[2] Futehally MA. Wind energy and OFIT: Wind energy for rural areas. Proceedings of the Netherlands International Workshop; The Netherlands 1991; pp. 59-63.

[3] Hasaan MU. Electrification of remote coastal areas through wind energy. Proceedings of the Conference on Renewable Energy Technologies and Sustainable Development; Islamabad, Pakistan 2005; pp. 39-48.

[4] Hassan MU. Development of renewable energy technologies in Pakistan - an overview. Islamabad: PCRET 2002.

[5] Chaudri QUZ. Wind energy potential of coastal areas of Sindh and Balochistan. Proceedings of the First National Workshop on PREGA; Islamabad, Pakistan 2002; pp. 19-27.

[6] Dawood R. Karachi port trust wind farm project: Project proposal submitted to ADB & PECRET. Karachi: Pakistan Venture Capital Limited 2002.

[7] Federal Bureau of Statistics. 50-years of Pakistan in statistics. Vol. I. Islamabad: Federal Bureau of Statistics, GoP 1998.

[8] Federal Bureau of Statistics. 50-years of Pakistan in statistics. Vol. III. Islamabad: Federal Bureau of Statistics, GoP 1998.

[9] Finance Division. Economic survey 2000-2001. Islamabad: Finance Division, GoP 2001.

[10] PPIB, Policy for new private independent power projects. Islamabad: Ministry of Water and Power, GoP 1998.

[11] Zaigham NA, Institutional capacities & barriers relevant to REGA technology promotion in Pakistan. ADB report: PREGA TA No. 5972-REG 2002.

[12] Zaigham NA, Nayyar ZA. Prospects of renewable energy sources in Pakistan. In: Khan HA, Qurashi MM, Hussain T, Hayee I, editors. Renewable-Energy Technologies and Sustainable Development. Islamabad: COMSATS 2005; pp. 65-86.

[13] New Zealand Ministry of Foreign Affairs & Trade [homepage on the Internet]. NZAID; c 2014 [cited 2006 Dec 20]: Available from: http://www.mft.govt.nz

[14] National Aeronautics & Space Administration NASA [homepage on the Internet]. Wilson J: NASA; c 2014 [cited 2006 Nov 23]: Available from: http://www.nasa.gov

[15] MODIS Website [homepage on the Internet]. Maccherone B: MODIS; c 2014 [cited 2006 Nov 25]: Available from: http://modis.gsfc.nasa.gov/

[16] NOAA Satellite Information System for NOAA Meteorological/Weather Satellite NOAASIS [homepage on the Internet]. NOAA; c2014 [cited 2006 Oct 10]: Available from: http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html

[17] SeaWIFS Project [homepage on the Internet]. Feldman GC: SeaWIFS; c2014 [cied 2007 Jan 5]: Available from: http://oceancolor.gsfc.nasa.gov/SeaWiFS/

[18] European Organization for the Exploitation of Meteorological Satellite [homepage on the Internet]. EUMETSAT; c2014 [cited 2007 Jan 15]: Available from: http://www.eumetsat.int/Home/index.htm

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