Karbala International Journal of Modern Science

Volume 6 | Issue 1 Article 8

The temporal and spatial distribution of wind factor in Iraq

Azhaar Mishaal
Ministry of Science and Technology, Baghdad, Iraq

Sura Nassir
Al-Karkh University of Science, Baghdad, Iraq

Ahmed Badr Khamees
Ministry of Science and Technology, Baghdad, Iraq

Mudar Ahmed Abdulsattar
Ministry of Science and Technology, Baghdad, Iraq, mudarahmed3@yahoo.com

The temporal and spatial distribution of wind factor in Iraq

Abstract

This work aims to study wind factor 10 m above the ground level for different stations in Iraq for determining the promising regions in the field of wind energy. For this purpose, the use of data (Wind Speed) for 25 years is performed. Missing data may occur within the time series of processing. Calculations are performed by using the statistical model (ARIMA model). The analysis of data is performed by using the Geographic Information System Program (Arc map). The temporal and spatial distribution of wind speed shows that the high value during the summer and the autumn in the southern stations (Hai, Nasiriyah, Basrah, Amara) can be considered as the promising regions in Iraq.

Keywords

Wind speed data; Statistical model; ARIMA model; GIS.

Cover Page Footnote

The references are changed to the journal style and the manuscript is checked for spelling and gramer errors.

1. Introduction

Atmospheric temperature changes due to the effects of solar radiation cause differences in atmospheric pressure. Therefore, the wind will be created according to the movement of air. The wind is generated by pressure differences so that air moves from places of high pressure to others with low pressure [1].

Each of the direction, speed, and gustiness are features of the wind. The wind is not seen, so we see things being moved by it. Then the movement of objects as air passes them is an indication of wind direction. Anemometers are used to measure wind speed. Beaufort scale can be used by ordinary people to indicate the speed of the wind from its influence on surroundings [2].

The Coriolis force increases when the wind speed increase. The stronger the wind, the greater the deflection. Coriolis force is one of the important factors that affect wind speed [3]. The direction of the wind is an important factor in the siting of a wind energy conversion system. It is reported by the direction from which it originates [3,4].

The power that can be extracted from the wind is one of the reliable sources to minimize the dependence on fossil fuel-generated electricity [5]. Wind power can be generated by using wind turbines [6].

In Iraq, Wind energy can be classified into three zones, 48% of Iraq has low annual wind speed, 35% has annual wind speed 3.1−4.9 m/s, 8% has relatively high annual wind speed, and the residual has calm values. The diurnal pattern of wind speed in Iraq has peak values at mid-day and early hours of the morning, the peak values of wind speed varies in the range 5−10 m/s [7].

The use of wind as a source of energy is becoming popular because it is clean and renewable. There is a pressing need in Iraq to develop site-based technology on wind energy, which can be used for the optimal design of wind farms. Therefore, the main objective of this paper was to analyze the statistical wind speed data obtained from measurements along a period of 25 years at 9 sites in Iraq, to indicate the superior sites among the selected sites with respect to the wind speed as well as knowing the best periods of wind speed during the year. A lot of research has been done around the world in the field of data mining for site assessment. Data mining using ARIMA or any other technique has been employed to analyzing wind speed data [8], wind speed prediction [9], and wind speed modeling for a wind farm and cost estimation [10].

2. Materials and methods

2.1. Study area

The time series for wind speed were used for different parts from Iraq in this work to draw map covering all region of Iraq which is located in the south-west of Asia between (29−37 N) and (39−48 E). Fig. 1 shows the study area.

2.2. Data

The monthly wind speed average data were obtained from Iraqi meteorological organization and seismology (IMOS) for (9) Stations. These data were analyzed using an arc map program, which is one of the Geographic Information System programs. Arc map was used to analyze the monthly mean wind speed for several stations (Mosul, Kirkuk, Khanqin, Baghdad, Hai, Dewaniya, Amara, Nasiriya, and Basrah), which are located at the north, middle and south of Iraq respectively for the period from (1985−2010). This period was divided into five parts from 1985 into 2010. The steps of each part are five years. Every year in this period (1985,1990, 1995, 2000, 2005, 2010) was divided into four months (Dec., Mar., Jul., Oct.), which correlate to the four seasons.

The Tables 1−4 containing data averages of wind speed for the nine stations, which show the spatial distribution for data sorted by seasons showing the temporal distribution.

2.3. Method of calculation of missing data

Missing data is a common problem in many kinds of researches. The way to deal with it depends on the amount of missed data, the kind of missing data, and the reasons the data are missing. There are many methods available to estimate missing data in meteorological researches; most of these methods can also be applied to many different fields, such as meteorology, astronomy, etc. [11].

If there is a small percentage of missing data, problems with analysis can be occurred, which leads to drawing the wrong conclusions. This means that, in the end, it may not have enough data to proceed in the analysis. Second, the analysis might run, but the results may not be statistically significant because of the small amount of input data. To solve this shortage of data,

https://doi.org/10.33640/2405-609X.1363

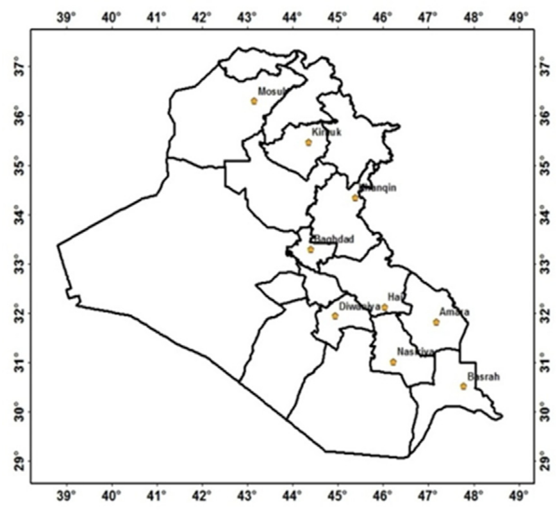


Fig. 1. The location of the studied stations in Iraq.

some statistical procedures automatically remove missing data. Box–Jenkins ARIMA (p, d, q) model is used to estimate missing data in the present work [12].

From these models: autoregressive integrated moving average (ARIMA) is the duration of the last three decades. Box–Jenkins ARIMA models use historical values of a single variable to forecast its future values. Thus, they are classified as a univariate model [13]. Box–Jenkins modes can be divided into four models: Auto-regressive model AR(p), Moving average model MA(q), Auto-regressive Moving Average model ARMA(p, q), and Auto-regressive Integrated Moving Average model ARMA(p, d, q) [14].

2.3.1. *Auto-regressive model AR (p)*

The number of terms in the model that describe the dependency among successive observations. Each term has an associated correlation coefficient that describes the

Table 1
Wind speed in winter.

Station	Longitude	Latitude	Jan-1985	Jan-1990	Jan 1995	Jan-2000	Jan 2005	Jan 1010
Mosul	43.15	36.31	2.3	0.8	0.8	1.9	Miss.	1.6
Kirkuk	44.35	35.47	0.5	1.1	0.9	1.2	1.5	2
Khanqin	45.38	34.35	3.2	2.4	1.4	1.3	1.3	0.9
Baghdad	44.4	33.3	1.7	2.7	2.2	2.5	3.1	3.8
Hai	46.03	32.13	5.3	3.6	3.6	3.8	2.7	3.2
Diwaniya	44.95	31.95	3.1	1.7	1.6	2.7	2.2	Miss
Nasiriya	46.23	31.02	3.8	3.5	2.5	2.7	2.7	3.3
Amara	47.17	31.83	2.3	3.4	3.4	4	3.3	2.6
Basrah	47.78	30.52	2.5	2.6	3.5	3.4	4.6	4.5

Table 2
Wind speed in spring.

Station	Longitude	Latitude	Mar-1985	Mar 1990	Mar-1995	Mar-2000	Mar 2005	Mar-2010
Mosul	43.15	36.31	0.5	1.8	1.1	1.7	Miss.	1.3
Kirkuk	44.35	35.47	1.1	13	1.1	1.3	2.2	1.8
Khanqin	45.38	34.35	1.5	3	1.8	1.6	1.3	Miss
Baghdad	44.4	33.3	2.2	3.6	3	3.2	3.4	3.6
Hai	46.03	32.13	5.6	3.7	3.7	5.1	3.5	Miss
Diwaniya	44.95	31.95	4.3	3	2.5	3.3	2.1	Miss
Nasiriya	46.23	31.02	4.6	5.7	3.9	4.7	3.2	3.4
Amara	47.17	31.83	3.7	5	4.7	5.9	4.2	3.4
Basrah	47.78	30.52	3.2	4.3	3.4	4.4	5.1	4.6

Table 3
Wind speed in summer.

Station	Longitude	Latitude	Jul-1985	Jul-1990	Jul-1995	Jul 2000	Jul 2005	Jul-2010
Mosul	43.15	36.31	1.2	1.8	1.7	2.4	1.6	1.5
Kirkuk	44.35	35.47	1.7	1.8	1.6	2.2	2.2	1.6
Khanqin	45.38	34.35	3	2.4	2.3	1.7	0.9	Miss.
Baghdad	44.4	33.3	3.7	4.3	4.2	3.2	4.2	3.5
Hai	46.03	32.13	7.1	6.2	6.9	5	5.5	Miss.
Diwaniya	44.95	31.95	5.3	3.2	3.5	3	2.8	Miss.
Nasiriya	46.23	31.02	8.9	7.5	8.2	4.3	4	4
Amara	47.17	31.83	8.5	6.9	9.8	5.3	5.3	4
Basrah	47.78	30.52	5.3	5.3	7.3	3.8	5.2	5.9

Table 4
Wind speed in autumn.

Station	Longitude	Latitude	Sep-1985	Sep-1990	Sep-1995	Sep 2000	Sep-2005	Sep-2010
Mosul	43.15	36.31	1.2	1.4	1	1.8	1	1
Kirkuk	44.35	35.47	1.6	0.9	1.2	1.2	1.6	1.1
Khanqin	45.38	34.35	2.4	2.2	1.8	1.3	0.9	Miss.
Baghdad	44.4	33.3	1.8	3.4	2.6	2.8	3.5	2.7
Hai	46.03	32.13	4	6.4	4.5	4.4	4.8	Miss.
Diwaniya	44.95	31.95	2.5	2.1	1.7	2.6	1.8	Miss.
Nasiriya	46.23	31.02	4.6	7.1	3.5	3.6	3.6	2.8
Amara	47.17	31.83	3.4	5.4	4.1	5.3	4.1	3
Basrah	47.78	30.52	2.8	5	3.6	4	5.4	3.9

magnitude of the dependency. For example, a model with two auto-regressive terms (p = 2) that mean the forecasted value depends on two previous observations.

The notation AR (p) indicates an autoregressive model of order p. The AR(p) model is defined as [15]:

$$\bar{y}_t = C + \varnothing_1\ y_{t-1} + \varnothing_2\ y_{t-2} + \ldots + \varnothing_P\ y_{t-p} \qquad (2-1)$$

Where $\varnothing_1$, $\varnothing_2$, ..., $\varnothing_P$ are the auto-regressive parameters, $\bar{y}_t$ is the forecasted value, p is the order of the AR, C is a constant (often omitted for simplicity) and $y_{t-1}, y_{t-2}, \ldots, y_{t-p}$ is the actual value.

2.3.2. *Moving average model MA(q)*

The number of terms that describe the persistence of a random shock (the random component of a time series) from one observation to the next. A model with two moving average terms (q = 2) is one in which an observation depends on two previous random shocks. The moving-average MA model is a common approach for modeling univariate time series models. The notation MA (q) refers to the moving average model of order q [16]:

$$\bar{y}_t = \epsilon_t - \theta_1\ \epsilon_{t-1} - \theta_2\epsilon_{t-2} - \ldots - \theta_q\ \epsilon_{t-q} \qquad (2-2)$$

where θ_1 , θ_2 , ... , θ_q are the moving average parameters, $\epsilon_t, \epsilon_{t-1}$, ϵ_{t-q} are the white noise terms. The value of (q) is called the order of the MA model.

2.3.3. *Auto-regressive moving average ARMA (p, q)*

The combination of the AR and MA models make up the ARMA model done on the stationarity time series when the d is generally equal to zero. The order of ARMA is represented as (p, q). Its compact form is written as [17]:

$$\bar{y}_t = C + \varnothing_1\ y_{t-1} + \ldots + \varnothing_P\ y_{t-p} + \epsilon_t - \theta_1\ \epsilon_{t-1} - \ldots - \theta_q\ \epsilon_{t-q} \qquad (2-3)$$

2.3.4. *Auto-regressive integrated moving average ARIMA (p, d, q)*

Autoregressive integrated moving average structure is ARIMA (p, d, q) where p = order of AR; d = number of differencing done on the non-stationarity time series; q = order of MA. The differencing is done to make the series stationary. This method is used when the model has higher fluctuation, and the d is generally greater than zero [18,19].

Box–Jenkins modes can be divided into models: Auto-regressive model AR(p), Moving average model MA(q), Auto-regressive Moving Average model ARMA (p, q), and Auto-regressive Integrated Moving Average model ARMA (p, d, q) [20].

In this work, the wind speed data [21], has missing data for several months within time series, about 15% of the total data. Table 5 shows the values of missing data (underlined) of wind speed in (m/s), which are mentioned in Tables 1–4 and identified with the word: missing (red color). These values were processed by using the ARIMA model.

The Promising Regions of wind Speed in Iraq, which are applied to the satellite image of the Terra -MODIS satellite with a resolution of 1 km [22].

Table 5
The values of missing data (underlined) on wind speed (m/s).

Station	Jan-2005	Mar-2005	Jan-1010	Mar-2010	Jul-2010	Sep-2010
Mosul	<u>1.6</u>	1.6	1.6	1.3	1.5	1.0
Khanqin	1.3	1.3	0.9	<u>0.7</u>	<u>2.3</u>	<u>0.9</u>
Hai	2.7	3.5	3.2	<u>3.5</u>	<u>5.0</u>	<u>3.0</u>
Diwaniya	2.2	2.1	<u>1.9</u>	<u>2.0</u>	<u>2.8</u>	<u>1.7</u>

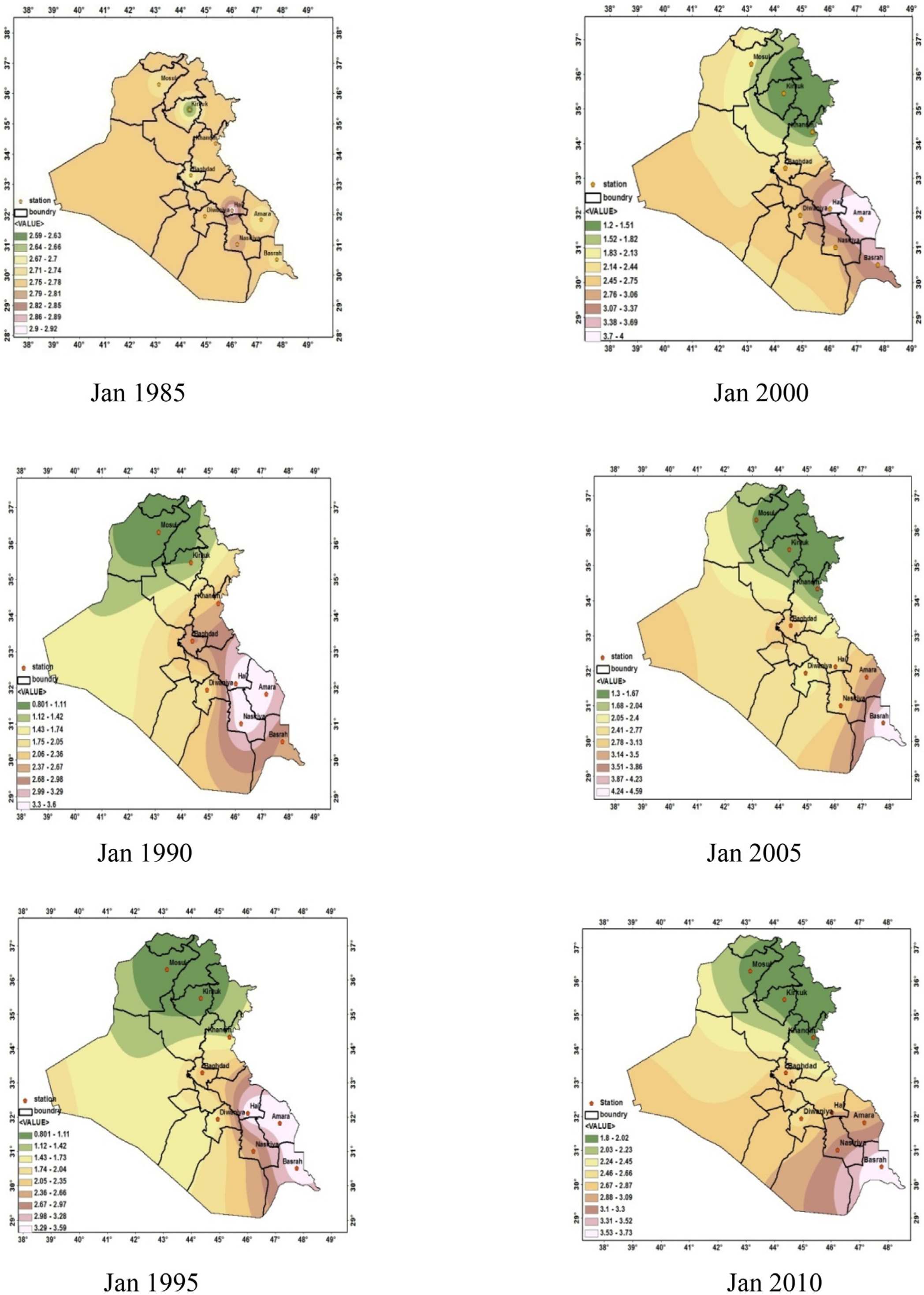
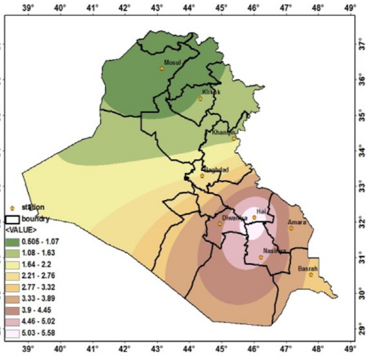
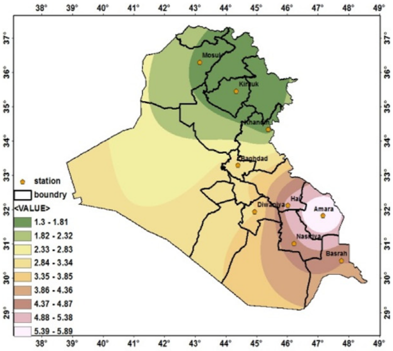


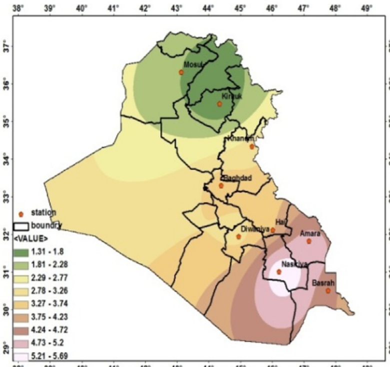
Fig. 2. Distribution of wind in winter.



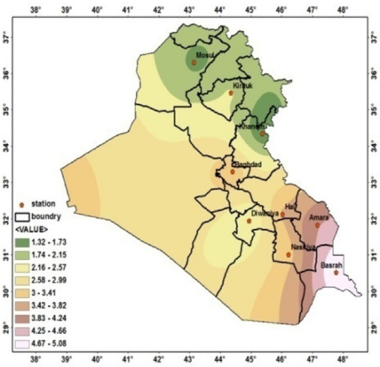
Mar 1985



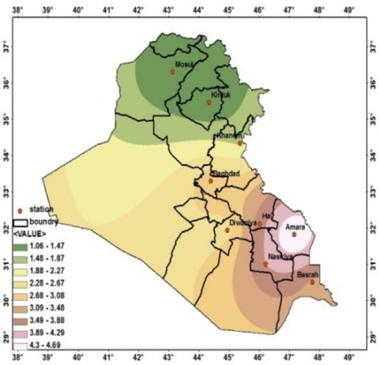
Mar 2000



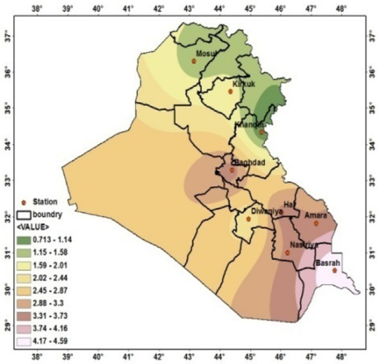
Mar 1990



Mar 2005



Mar 1995



Mar 2010

Fig. 3. Distribution of wind in spring.

3. Results and discussion

By analyzing the data using an arc map program, several maps obtained, which explained the Temporal and Spatial distribution of wind speed in Iraq. The maps below show the mean wind speed for all stations.

Fig. 2 shows the average wind speed during the winter season in Iraq that ranged between (0.8−4.5 m/s). Fig. 3 shows the average wind speed during the

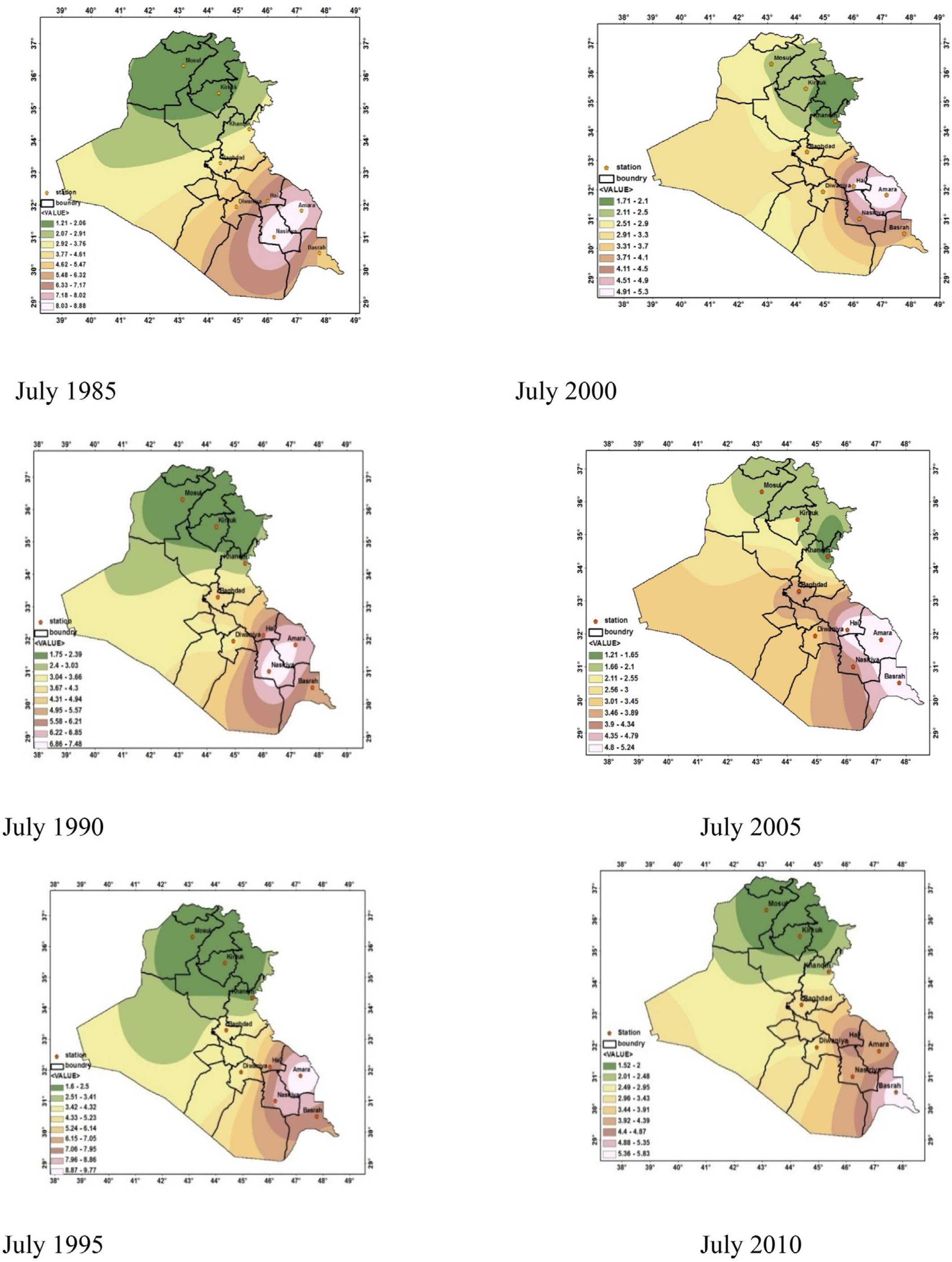


Fig. 4. Distribution of wind in summer.

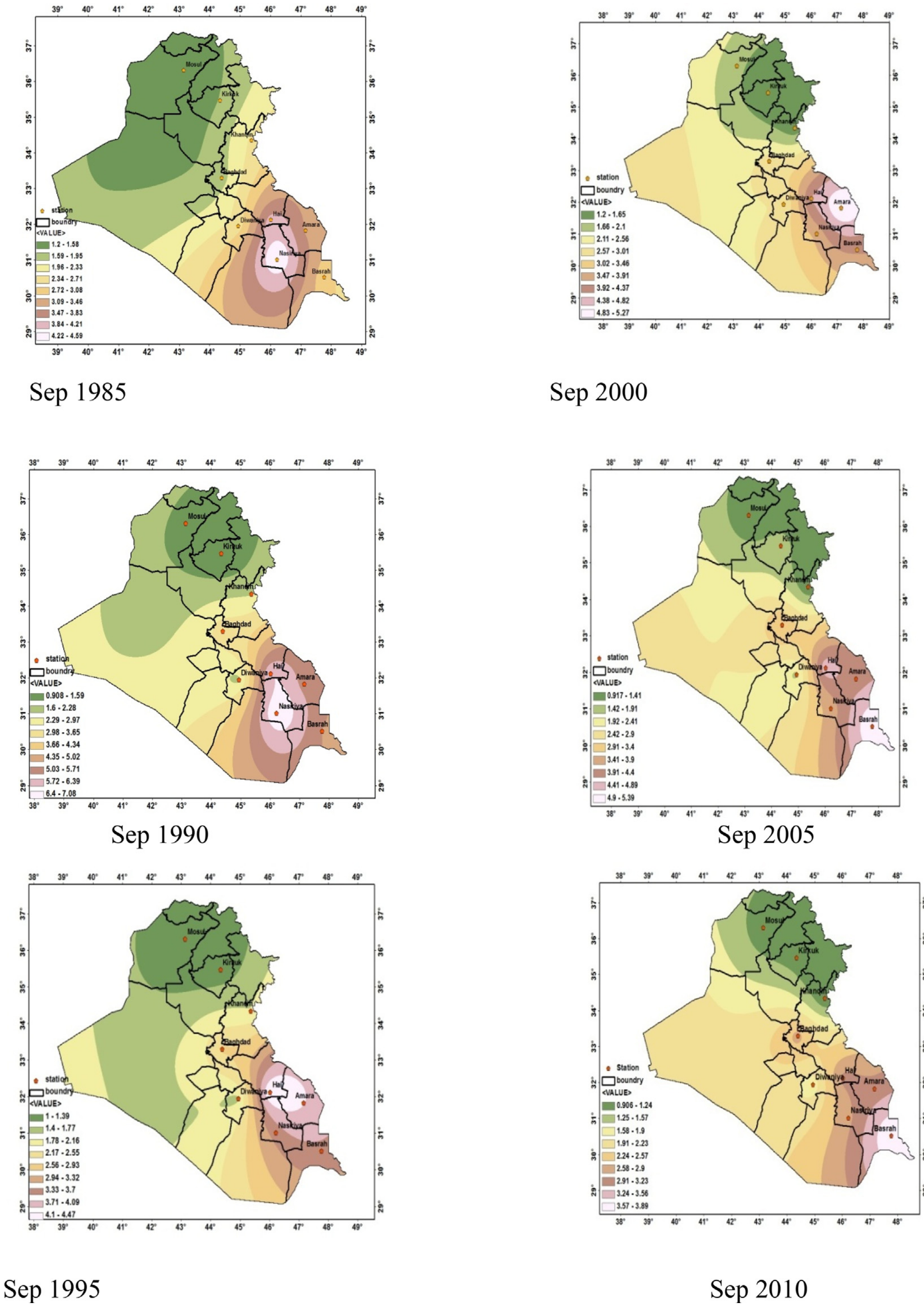


Fig. 5. Distribution of wind in autumn.

Spring season, which is ranged between (0.5−5.5 m/s) in spring, while the range of the average wind speed in Fig. 4 is between (1.2−9.4 m/s) in the summer season. Finally, in Fig. 5, the range of the average wind speed is between (0.9−7.08 m/s) in autumn.

Certain years have been selected in this work in a sequence of 5 years period starting in the year 1990. This is because the change in wind speed becomes evident when it studied for several years as well as reducing the huge data and maps when the data studied annually.

In the Figs. 2−5, it is possible to exist of some errors which are found duo to the analyzed data, the data were hourly and recorded at 10 m in height as well as the accuracy of the calculations. Generally, a good indication and evident scope can be obtained from this data.

The analyzed data of all sites have been illustrated in four sets of maps as follow:

From these values, it was noted that the peak wind speed reaches (9 m/s) in summer and autumn. Moderate wind speed reaches (5 m/s) in spring, and low wind speed does not exceed (4.5 m/s) in winter. This is called the temporal distribution for the wind. By using the Arc map program, the analysis shows that the peak wind speed in the southern regions (Hai, Amara, Basrah, Nasiriyah) can be considered as Promising Regions along the period of studied areas.

Fig. 6 shows the Promising Regions of wind Speed in Iraq.

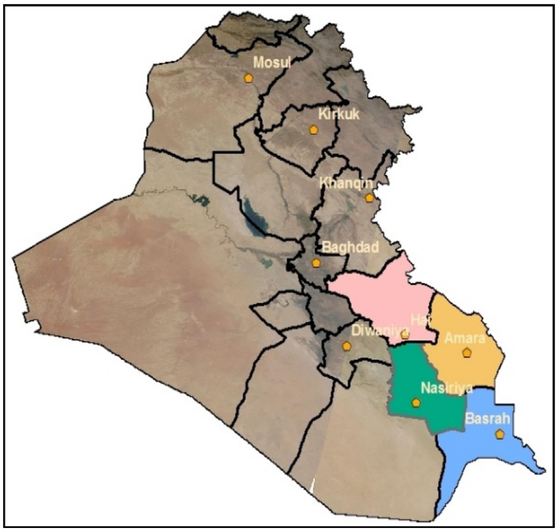


Fig. 6. Promising regions of wind speed in Iraq.

4. Conclusions and recommendations

4.1. Conclusions

1- The temporal distribution of the selected sites in Iraq showing that the wind speeds have maximum values in summer and autumn while they are at lower values in winter.

2- The spatial distribution of wind speed shows that (Hai, Nasiriya, Amara, Basrah) sites can be considered as promising regions.

3- It is possible to install wind farms in promising regions determined in this research to produce electric power from wind energy.

4- Depending on the wind speed values during spring, summer, and autumn, it is possible to install hybrid systems (wind turbine & solar panels) in the promising regions to make use in the generation of electric power and water pumping.

4.2. Recommendation

5- It is possible to study the relationship between wind speed and other meteorological elements like Pressure Systems (Anticyclone and Cyclone), relative humidity, and Temperature to show their Impacts on the wind speed in Iraq.

References

[1] A.K. Azad, M.M. Alam, I.M. Rafiqul, Statistical analysis of wind gust at coastal sites of Bangladesh, Int. J. Energy Machinery 3 (2010) 9−17.

[2] J.C. Chadee, C. Sharma, Wind speed distributions: a new catalogue of defined models, Wind Eng. 25 (2001) 319−337.

[3] C.D. Ahrens, Meteorology Today: an Introduction to Weather, Climate, and Environment, West publishing company, St. Paul, Minnesota, USA, 1985.

[4] S. Mathew, Wind Energy Fundamentals, Resource Analysis and Economics, Springer-Verlag, Berlin Heidelberg, 2006.

[5] J. Andrews, N. Jelley, Wind Power. Energy Science, Principles, Technologies and Impacts, Oxford University Press Inc., New York, 2007.

[6] R.D. Richardson, G.M. McNerney, Wind energy systems, Proc. IEEE 81 (1993) 3.

[7] S.T. Ahmed, Review of Solar Energy and Alternative Energies Applications in Iraq, the First Conference between Iraqi and Germany Universities DAAD, Arbil, Iraq, 2010.

[8] Marwa F. Al-Roby, Alaa M. El-Halees, Data mining technique for wind speed analysis, A cse study for Gaza Strip, J. Comp. Eng. 2 (2011) 1−5.

[9] Erasmo Cadenas, Wilfrido Rivera, Rafael Campos-Amezcua, Christopher Heard, Wind speed prediction using a univariate ARIMA model and a multivariate NARX model, Energies 9 (2016) 109.

[10] A.K. Rajeevan, P.V. Shouri, Usha Nair, ARIMA based wind speed modeling for wind farm reliability analysis and cost estimation, J. Electr. Eng. Technol. 11 (2016) 709−718.
[11] E.P. George, G.M.J. Box, C.R. Gregory, Time Series Analysis, fourth ed., John Wiley & Sons, Inc., 2008.
[12] J. George, The box-jenkins forecasting technique, Annu. Rev. Psychol. 62 (2006) 9−11.
[13] G.E. Box, G.M. Jenkins, Time Series Analysis; Forecasting and Control, second ed., Prentice-Hall Inc., New Jersey, 1976.
[14] V. Ramasubramanian, Forecasting techniques in agriculture, Indian Agricultural Statistics Research Institute, library avenue, new Delhi, 2006.
[15] X. Zhu, M. Shen, Discussions of Three Mathematical Models of Wind Power Prediction in Practice. Dep. Of Basic Sci., Huazhong Univ. of Sci. and Tech. Wuchang Branch, Wuhan .430064, China, Hubei Electric Power Survey & Design Institute, Wuhan. 430024, China, 2006.
[16] K. Gnana Sheela, Computing models for wind speed prediction in renewable energy systems. IJCA special issue on "computational science - new dimensions & perspectives", NCCSE (2011) 108−111.
[17] M. Milligan, M. Schwartz, Y. Wan, Statistical Wind Power Forecasting Models: Results for, U.S. Wind Forms, Austin, TX, 2003, pp. 18−21.
[18] P.S. Chang, L. Li, Ocean surface wind speed and direction retrievals from the SSM/I, IEEE Trans. Geosci. Rem. Sens. 36 (1998) 1866−1871.
[19] A. Boone, Simulation of Short-Term Wind Speed Forecast Errors Using a Multi-Variate ARMA (1,1) Time-Series Model. Master's Thesis for Master of Science Degree in Sustainable Energy Engineering, Dept of Electrical Engineering Electric Power Systems Stockholm, Sweden, 2005, pp. 9−13.
[20] C.W. Potter, M. Negnevitsky, Very short-term wind forecasting for Tasmanian power generation, IEEE Trans. Power Syst. 21 (2006) 965−972.
[21] General Commission for Iraqi Atmospheric Seismic Monitoring, Climate Section, 2018. Unpublished data, Baghdad, Iraq.
[22] http://modis.atmos.gcfc.nasa.gov./IMAGES/MOD02/GRAUIE. (Accessed 18 February 2018).