Techno-Science 2:3 (2019) 47-53

Techno-Science
Scientific Journal of Mehmet Akif Ersoy University
www.dergipark.gov.tr/sjmakeu

Original Research Article

hosted by Turkish JournalPark ACADEMIC

Prediction of wind blowing durations of Eastern Turkey with machine learning for integration of renewable energy and organic farming-stock raising

Ali Hakan Işık[1], Fatma Kadriye Düden Örgen[2], Ceylin Şirin[2], Azim Doğuş Tuncer[2*], Afşin Güngör[3]

[1] Department of Computer Engineering, Faculty of Engineering-Architecture, Burdur Mehmet Akif Ersoy University, Burdur, Turkey
[2] Department of Energy Systems Engineering, Faculty of Engineering-Architecture, Burdur Mehmet Akif Ersoy University, Burdur, Turkey
[3] Bucak Faculty of Technology, Burdur Mehmet Akif Ersoy University, Burdur, Turkey

ARTICLE INFO

Article History

Received	:	27/02/2019
Revised	:	12/06/2019
Accepted	:	17/09/2019
Available online	:	30/09/2019

Keywords
Wind energy prediction
Wind blowing duration
Artificial neural networks
Machine learning
Organic farming, Livestock raising

ABSTRACT

Applications which integrate wind energy and both agriculture and stock raising are increasingly becoming popular especially in Europe. Subject applications enable the land to be utilized in various favorable ways. In this study, by using a 5-year average wind data referring to Erzurum and Ardahan, two eastern cities of Turkey which are characterized by prevailingly an extensive cattle-raising, wind-blowing durations were calculated by Rayleigh distribution. Annual wind blowing durations for Erzurum and Ardahan ranged between 479.6-5825.7 hours and 1643.6-6710.8 hours, respectively. The data obtained was predicted via artificial neural networks and output results indicate an prediction accuracy at 99% level thereupon. The integration of agricultural and stock raising activities with wind energy shall contribute to environmental aspects as well increasing the efficiency and effectiveness in the region.

1. INTRODUCTION

Global energy needs are increasing rapidly in accordance with the increasing population. Due to depletion and their environmental damage, the fossil fuels used today to meet the energy needs are being replaced by renewable energy sources. Wind energy is a renewable energy source that is increasingly used in our country. Wind energy generation in a certain region depends on the performance characteristics and operating conditions of the wind on that specific region. It would not be possible to determine a stable model for the system where and if the wind velocity and the output power data have frequently variable characteristics. Hence, the amount of wind energy to be generated will be closely related to the wind velocity in that region. The energy which can be generated on a wind turbine depends on several parameters such as the wind velocity, the tower height of the wind turbine, the wing diameter, the density of the zone, and the wind-blowing duration.

Organic farming activities gained a worldwide momentum due to the fact that consumers in advanced countries have come to realize the damages caused by industrial processes to human health as well as environment. This type of production activity has spread rapidly all over the world and it has been observed that it was possible to yield a richer aroma in the products grown under organic farming conditions. Organic livestock activities have survived from the 1980s onwards. The main goal in this kind of activity is to restore the natural balance which tended to be lost in the ecosystem and to give weight to animal health, as well as human health [1]. Besides, industrial agriculture and stock raising generally require high energy consumption. This requirement brings about economic and environmental problems. In order to prevent these problems, the issue of agricultural and stock raising applications integrated with renewable energy have become an important research topic in recent years, particularly in European countries.

* Corresponding Author: azimdtuncer@gmail.com

To cite this article: Işık, A.H., Düden Örgen, F.K., Şirin, C., Tuncer, A.D., Güngör, A. (2019). Prediction of wind blowing durations of eastern turkey with machine learning for integration of renewable energy and organic farming-stock raising *Techno-Science* vol. 2, no. 3 p. 47-53.

Likewise its utilization in many other areas, artificial neural networks (ANN) have been used also for the determination of wind data such as wind velocity data and blowing duration of wind. By using statistical methods plus ANN, Kırbaş predicted the short-term multi-step wind velocity [2]. Using the wind velocity data for Akhisar region, Ata predicted the wind-blowing duration of that region with ANN [3]. Gnatowska and Moryn-Kucharczyk evaluated the wind energy perspective in Poland particularly in terms of wind power. He emphasizes the significance of state support in the production of wind energy in his study [4]. In an attempt to increase the estimation quality in wind energy studies, Yan and Ouyang suggested a new approach and verified their study in a real-world wind production facility [5]. In their study, which well summarized the characteristics of wind energy, Güngör and Eskin examined the deficiencies in previous studies, while also pointing out the possible future development areas in energy envisionings. [6]. In his study, Güngör investigated the effect of global warming on the potential of wind energy [7].

In this study, by using the wind velocity data at an altitude of 10 meters in Ardahan and Erzurum which was obtained from Turkish General Directorate of Meterological Affairs (GDMA) [8], wind blowing durations were calculated. Wind blowing durations obtained were predicted with ANN. The present study aims at integrating the renewable energy sources with agriculture and stock raising, and is intended to be served as an example for respective engineers, designers and planners in this regard.

2. AGRICULTURAL AND LIVESTOCK CHARACTERISTICS IN THE STUDIED REGION

The urbanization rate in Erzurum is below Turkey's average and rural employment in the city constitutes 62.3% of total employment. These socio-economic indicators suggest that stock raising is important for the provincial economy and will preserve this importance in the near future. Number of milked cattle in Erzurum constitutes 4.5% of the total milked cattle in Turkey, while its contribution to Turkey's total milk production amounts to 4.3% of the overall milk production in the country. The presence of sheep and goat in the province has demonstared a significant decline in recent years. As for 2017 data, there are 730.000 cattle and 714.000 sheep and goat in Erzurum [9,10].

Due to elevation features and air masses effective throughout the year, a harsh continental climate is dominating in Ardahan. Based on these parameters, the average temperature is below -10 °C in winter and is about 16-17 °C in summer period. According to the official data of the GDMA, the average annual temperature is 3.7 °C. The highest temperature in Ardahan is measured as 16.3 °C in July, whereas lowest temperature values are measured in January. In addition, due to its geographical location, the large mountain ranges in southwest-northeast direction are found to have an altitude about 2000-2200 meters whereas in volcanic masses it even reaches to 3000 meters and over. Due to the fact that the climatic conditions are convenient for agriculture, the proportion of land allocated to agriculture in the province is around 17%, 80% of which is assigned to grain products. In the remaining areas, the mostly cultivated product group is forage crops. Through some narrow areas in the vicinity of Posof and in Kurtkale basin which enable pomiculture, a variety of fruits are grown such as apples and walnuts [11].

Cattle raising is of particular importance in Ardahan and is mainly represented by beef raising. While there is more cattle in the central district and Göle with their larger grassland areas, in the villages of Posof basin the number is much fewer due to lack of pasture areas. Small livestock in the province is basically represented by sheep raising. It is mostly raised in the central district and Çıldır. Poultry farming, which is mainly forefronted by goose breeding, is a city-wide common activity. Other poultry includes chicken, turkey and duck [11].

Considering the agricultural and livestock activities and the potential in the region, it can be suggested that these activities can be increased through several governmental promotions and support. Rough and high mountainous areas in the region is one of the main factors restricting the effective use of region's available lands. Besides, agricultural and stock raising activities when supported by future wind power plants in the region shall contribute to the efficient use of the area.

3. DESIGN

There are varios methods available in the literature to determine the wind energy potential of a region, yet, the most commonly used ones are the Weibull and the Rayleigh distributions. In order to determine the duration and distribution of the wind in a region during a given period, in addition to the Weibull distribution, Rayleigh distribution is used by taking the shape parameter in the probability density function as two. Generally, the Rayleigh distribution is used when only the average velocity value is known for the region.

Rayleigh density function is shown as below;

$$f_R(v) = \frac{\pi}{2} * \frac{v}{v_{ort}^2} \exp(-\left(\frac{\pi}{4}\right) * \left(\frac{v}{v_{ort}}\right)^2 \quad (1)$$

Rayleigh cumulative distribution function is shown as below;

$$F_R(v) = 1 - \exp(-\frac{\pi}{4}(\frac{v}{c})^2) \quad (2)$$

where; c is parameter of scale (m/s). The biggest advantage of the Rayleigh distribution function is that it can determine the wind distribution of a given region depending only on the average velocity. The blowing velocity/hour can be calculated according to the Rayleigh distribution function with the help of Equation 3 [12].

$$h_r = f_R(v) * 8760 \quad (3)$$

The average annual wind velocity data for Ardahan and Erzurum at altitude of 10 m for the years 2014-2018 are given in Table 1 and 2, respectively [8]. Out of five-year histrorical data regarding Ardahan, the highest average wind velocity is featured in station no.3 (Çıldır) with 3.515 m/sec. The lowest average wind velocity featured in the same city belonged to station no.2 (Posof) with 0.951667 m/s. In Erzurum, while the station no.25 (Karaçoban) is observed as having the lowest wind velocity with 1.41 m/s, the highest value appeared in station no.12 (Yakutiye) with 4.180 m/s.

Table 1. *The average annual wind velocity data for Ardahan [m/s] [8]*

Measurement station	Province/region	2014	2015	2016	2017	2018
1	Ardahan	1.25	1.283333	1.025	1	0.991667
2	Posof	0.866667	0.883333	1.1	0.991667	0.916667
3	Çıldır	3.683333	3.383333	3.65	3.425	3.433333
4	Damal	2.466667	2.575	2.7	2.608333	2.516667
5	Göle	2.108333	2.141667	2.216667	2.083333	2.091667
6	Hanak	2.025	2.091667	2.116667	2.208333	2.05

Table 2. The *average annual wind velocity data for Erzurum [m/s] [8]*

Measurement station	Province/region	2014	2015	2016	2017	2018
7	Erzurum	1.458333	1.391667	1.466667	1.341667	1.391667
8	Erzurum Airport	3.083333	2.783333	3.4	3.025	2.575
9	Uzundere	1.666667	1.791667	1.783333	1.8	1.883333
10	İspir	1.666667	1.716667	1.741667	1.641667	1.783333
11	Oltu	2.175	2.133333	2.058333	2.125	1.975
12	Yakutiye	4.857143	4.75	4.714286	3.166667	3.414286
13	Palandöken	4.033333	3.4125	3.366667	3.641667	3.77
14	Aziziye	4.011111	9.74	3.022222	2.755556	2.366667
15	Tortum	1.441667	1.491667	1.483333	1.541667	1.425
16	Horasan	1.141667	1.2	1.15	1.166667	1.233333
17	Aşkale (Kop Mountain)	3.375	3.7	4.036364	3.2	3.025
18	Hınıs	1.258333	1.35	1.4	1.308333	1.416667
19	Palandöken Ski Center	4.866667	3.4	3.95	3.85	4.033333
20	Pasinler	4.008333	3.916667	2.833333	2.375	2.266667
21	Narman	1.908333	1.85	1.925	1.958333	1.808333
22	Çat	3.358333	3.916667	2.683333	2.308333	2.291667
23	Karayazı	3.125	3.25	3.391667	3.175	3.175
24	Aşkale	1.35	1.525	2.275	2.183333	2.083333
25	Karaçoban	1.233333	1.183333	1.083333	1.025	1.358333
26	Köprüköy	2.375	2.291667	2.45	2.2	2.216667
27	Olur	2.008333	2	2.066667	2.1	2
28	Pazaryolu	2.641667	2.55	2.6	2.35	2.583333
29	Şenkaya	2.525	2.55	2.558333	2.633333	2.5
30	Tekman	2.633333	2.391667	2.641667	2.35	2.375
31	Çayırözü	2.428571	2.533333	2.166667	2.2	2.391667

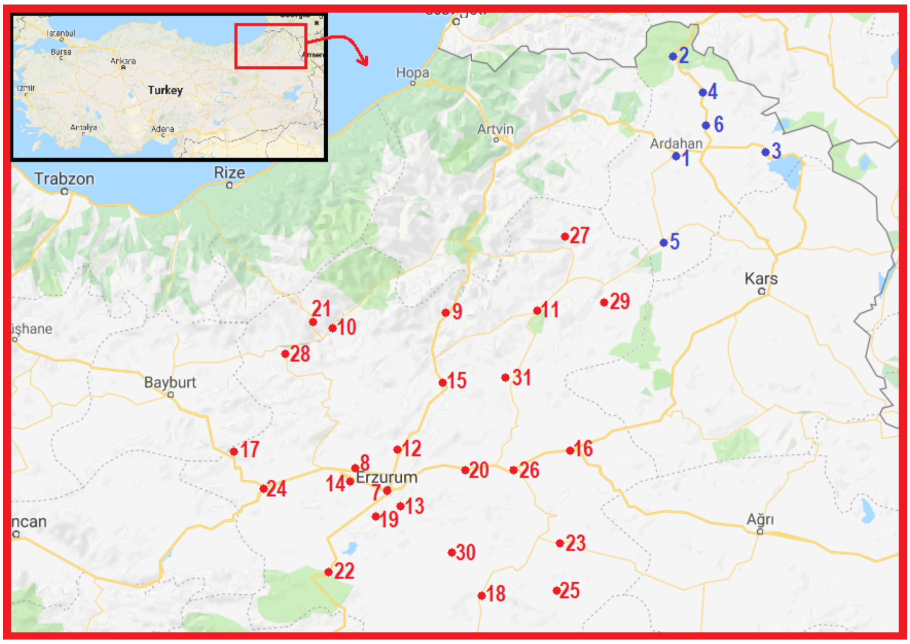

Fig. 1. *Locations of the measurement stations*

Fig.1 shows the locations of the measurement stations from which the data is collected. Blue and red colors demonstrate the stations in Ardahan and Erzurum, respectively. As can be followed clearly from the figure, the measurement stations cover a satisfactorily large area and can well generate comprehensive results about the regions under study.

4. SOLUTION METHOD

In this study, feedback propagation learning algorithm was used to determine the wind blowing duration. The study benefited from the artificial neural network toolbox which is available in MATLAB/Simulink software package. Normalization techniques were applied to input values in order to improve the performance results. The input and output data of the ANN which was obtained from the GDMA consist of 70% training cluster, 15% validation cluster and 15% test cluster, which amounted as 1249, 268 and 268 data figures, respectively. The performance analysis of the neural network was evaluated by the Mean Square Error (MSE) and the Regression curve. According to the test results, the best results for wind blowing duration prediction were obtained via 9 hidden layer architecture. Network was trained using the Levenberg-Marquardt optimization technique. Using input/output values, different network configurations are trained in order to produce minimum Mean Square Error (MSE) and maximum regression values. The ANN architecture designed for the study is given in Fig. 2.

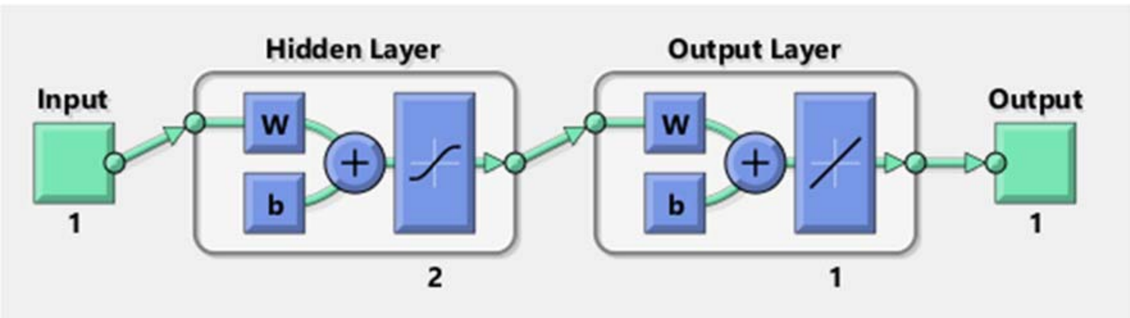

Fig. 2. *Developed ANN structure*

5. RESULTS AND DISCUSSION

The results indicate that, the station with the maximum wind duration in Ardahan is Posof, while the station with the least blowing duration is station no.3. Similarly, the maximum and minimum wind blowing duration in Erzurum belong to station no.25 and no.12, respectively. Maximum wind blowing durations occured in the areas which had minimum wind velocity; and, just in contrast, minimum wind blowing durations occured in the areas with maximum wind velocity. Table 3 and Table 4 depict the annual average values (in hours) of wind blowing durations produced via Equation 3. It can be observed that wind-blowing durations for the areas under study vary between 479.6-5825.7 hours and 1643.6-6710.8 hours per year for Erzurum and Ardahan, respectively.

Table 3. *Annual average values (in hours) of wind blowing durations of Ardahan (hrs/year)*

Measurement station	Province/region	2014	2015	2016	2017	2018
1	Ardahan	4733.203	4370.249	5756.821	5658.453	6041.088
2	Posof	6495.56	6710.821	5324.31	5846.948	6345.464
3	Çıldır	1646.835	1805.675	1643.636	1765.14	1755.765
4	Damal	2337.085	2343.559	2213.281	2297.478	2413.2
5	Göle	2763.522	2747.942	2693.202	2814.068	2909.252
6	Hanak	2840.275	2869.319	2810.844	2667.931	2917.438

Table 4. *Annual average values (in hours) of wind blowing durations of Erzurum (hrs/year)*

Measurement station	Province/region	2014	2015	2016	2017	2018
7	Erzurum	4145.23056	4165.447	4000.046	4268.346	4250.11
8	Erzurum Airport	1955.67937	2087.265	1765.158	1871.672	1260.116
9	Uzundere	3143.11204	2989.538	3070.985	2997.615	2973.711
10	İspir	3582.86985	3414.167	3440.17	3636.309	3379.16
11	Oltu	2811.79328	2887.914	2995.521	2871.655	3129.309
12	Yakutiye	743.355147	479.62	1181.252	1387.385	1200.451
13	Palandöken	1450.10758	1214.802	1841.948	1699.523	1338.103
14	Aziziye	1034.91279	120.0423	1604.926	2285.331	2373.665
15	Tortum	4244.62423	3961.477	4089.219	4035.151	4257.486
16	Horasan	5114.41945	4791.188	5119.905	4967.086	4946.985
17	Aşkale	1628.93456	1393.711	1407.308	1450.408	1999.496
18	Hınıs	4671.12966	4472.484	4294.659	4632.293	4299.778
19	Palandöken	1225.52058	154.1213	1562.849	1615.985	1523.813
20	Pasinler	1497.82276	1530.157	2064.185	2508.328	2658.609
21	Narman	3066.36423	3144.852	3124.87	3021.858	3351.015
22	Çat	1807.19975	1507.764	2172.554	2555.485	2652.498
23	Karayazı	1941.27699	1906.42	1804.562	1918.092	1918.092
24	Aşkale	4340.22092	3854.256	2625.005	2747.386	2900.057
25	Karaçoban	4716.85948	4982.754	5567.42	5825.745	4377.563
26	Köprüköy	2458.29597	2518.716	2428.775	2592.623	2717.93
27	Olur	2885.8709	3016.304	2879.499	2834.338	2985.84
28	Pazaryolu	2191.1886	2251.299	2221.07	2411.023	2326.168
29	Şenkaya	2313.407	2319.602	2362.507	2279.923	2444.502
30	Tekman	2228.62933	2451.254	2240.628	2441.056	2539.75
31	Çayırözü	1426.98881	1179.395	665.2048	2706.959	2514.132

Table 5. *Regression and MSE for different architecture.*

Hidden Layer	Regression			Validation MSE	Epoch
	Training	Validation	Test		
2	0.9894	0.9851	0.9820	0.011	800
3	0.8918	0.9315	0.8800	0.017	800
4	0.8874	0.9232	0.9366	0.016	800
5	0.9001	0.8879	0.9239	0.024	800
6	0.8943	0.9247	0.9097	0.018	800
7	0.8951	0.8869	0.9360	0.026	800
8	0.9001	0.8970	0.9156	0.025	800
9	0.9048	0.8721	0.9112	0.026	800
10	0.8951	0.8932	0.9042	0.028	800

A given regression result converging to 1 represents a close relationship between variables, while they are meant to have a weaker relationship when the regression result converges to 0. As shown in Fig. 3, the results of the network with 2 hidden layer have a regression value of approximately 1, which means that ANN successfully predicts the unknown data.

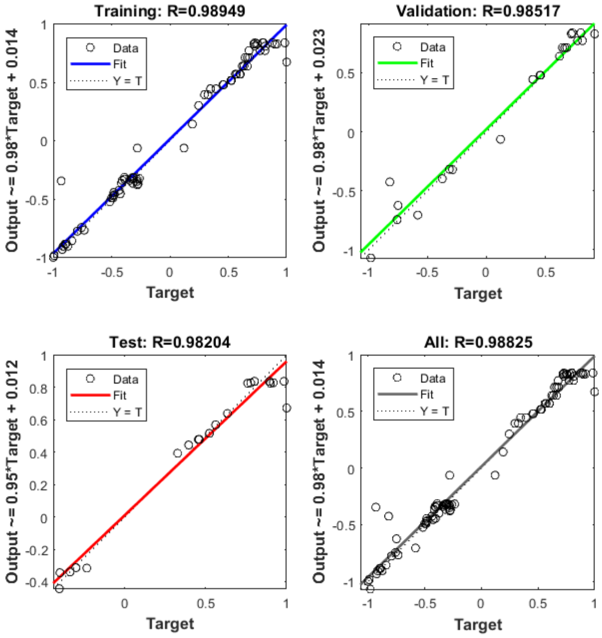

Fig. 3. *Regression results of ANN*

The output function obtained as a result of ANN modeling and prediction of the data is provided in Fig. 4, and error histogram and validation MSE obtained from the study are given in Fig. 5. As expected, maxiumum error values shown in Fig. 5 are noted to occur during the training of the network.

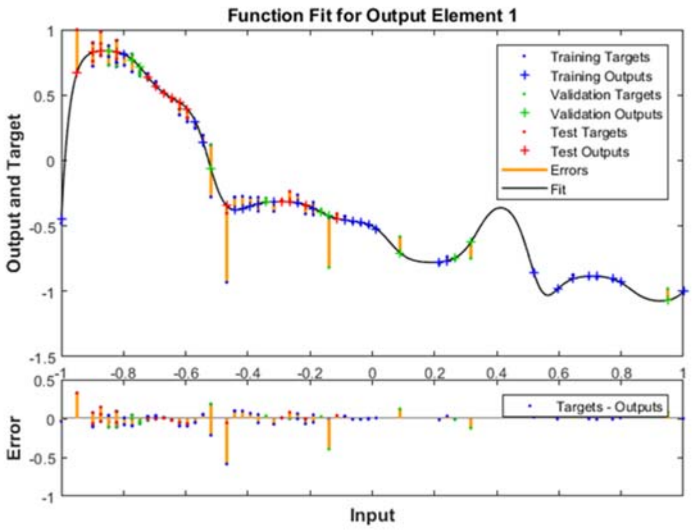

Fig. 4. *Simulation and Real Values of Data*

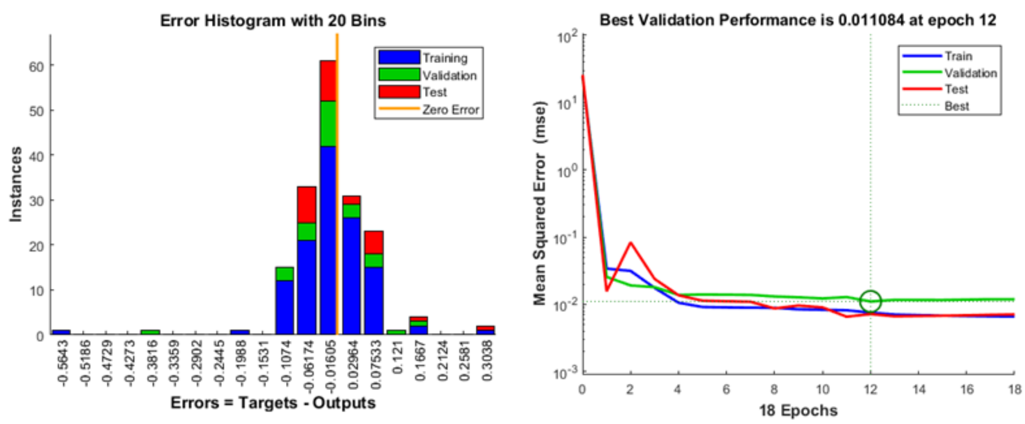

Fig. 5. *Error histogram of ANN modeling (left), Validation MSE values (right)*

6. CONCLUSIONS

As a renewable energy source, durableness of wind energy and pre-measurements for turbine installation are of great importance. The installation of the wind turbine at an optimal location is a parameter that directly affects the amount of electrical energy to be obtained. In this study, wind blowing durations in Erzurum and Ardahan, two eastern cities in Turkey, where cattle raising and agriculture activities are carried out, were determined with Rayleigh distribution and the results were predicted by artificial neural networks which is one of the techniques of machine learning. Prediction results performed a 99% accuracy. The current study showed that agriculture and stock raising activities would be carried out in integration with wind energy, especially for the locations with long wind blowing durations. Considering the high performance rates as for the prediction of artificial neural networks, this method is promising in predicting several other parameters regarding wind energy.

As far as the regions under study is concerned, it is possible to assert that these regions can be improved in terms of energy as well as agriculture and stock raising. Integrating agriculture and stock raising activities with wind energy, which is a sort of renewable energy, would yield to increase the efficiency and effectiveness and make favorable contributions to environment.

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Techno-Science *Paper ID: 533211*