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Water Quality Assessment and Total Dissolved Solids Prediction using Artificial Neural Network in Al-Hawizeh Marsh South of Iraq

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ABSTRACT

The Iraqi marshes are considered the most extensive wetland ecosystem in the Middle East and are located in the middle and lower basin of the Tigris and Euphrates Rivers which create a wetlands network and comprise some shallow freshwater lakes that seasonally swamped floodplains. Al-Hawizeh marsh is a major marsh located east of Tigris River south of Iraq. This study aims to assess water quality through water quality index (WQI) and predict Total Dissolved Solids (TDS) concentrations in Al-Hawizeh marsh based on artificial neural network (ANN). Results showed that the WQI was more than 300 for years 2013 and 2014 (Water is unsuitable for drinking) and decreased within the range 200-300 in years 2015 and 2016 (Very poor water). The developed ANN mode gave a high correlation coefficient reaching 0.927 for the prediction of TDS from the model and showed high levels of TDS in Al-Hawizeh marsh that pose threats to people using the marsh for drinking and other uses. The dissolved Oxygen concentration has the highest importance of 100% in the model because the water of the marsh is fresh water, while Turbidity had the lowest importance.

Keyword: assessment, Iraqi marshes, Al-Hawizeh, artificial neural network (ANN) model, TDS, water quality index.

تقييم نوعية المياه والتنبؤ للمواد الصلبة الذائبة الكلية باستخدام الشبكة العصبية الاصطناعية في هور الحويزة جنوب العراق

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الخلاصة

تعتبر الأهوار العراقية في الحوض الأوسط والسفلي لنهر دجلة والفرات من أكثر النظم الإيكولوجية الرطبة انتشارا في الشرق الأوسط .وفي دوراتها الدنيا، أنشأت نهري دجلة والفرات شبكة من الأراضي الرطبة المعروفة بالأهوار في بلاد ما بين النهرين .إن الأهوار الرئيسية في العراق هي مستنقعات الحويزة الواقعة شرق نهر دجلة جنوب العراق، وتشتمل هذه الأراضي الرطبة على بحيرات المياه العذبة الضحلة المترابطة والمستنقعات وسهول الفيضانات المستنقعة موسميا. تهدف هذه الدراسة إلى تقييم نوعية المياه من خلال مؤشر نوعية المياه (WQI) والتنبؤ بالتركيزات الكلية للاملاح الذائبة في هور الحويزة على أساس الشبكة العصبية الاصطناعية (ANN). وأظهرت النتائج أن مؤشر جودة المياه كان أكثر من 300 لسنوات 2013 و 2014 (المياه غير مناسبة للشرب) وانخفض ضمن نطاق 200-300 في عامي 2015 و 2016 (المياه سيئة جدا). ان استخدام برنامج (ANN) نموذجا ذو معامل الارتباط عالية تصل إلى 0.927 للتنبؤ (TDS) من النموذج وأظهرت مستويات عالية من

تراكيز المواد الصلبة الذائبة في أهوار الحويزة التي تشكل تهديدا للأشخاص الذين يستخدمون الأهوار للشرب وغيرها من الاستخدامات. ان تركيز الأوكسجين المذاب له أعلى أهمية 100٪ في النموذج لأن ماء الأهوار هو ماء عذبة، في حين أن العكارة كانت أقل أهمية.
مفاتيح الكلمات: تقييم، اهوار العراق، الحويزة، نموذج الشبكة العصبية، المواد الكلية الصلبة الذائبة، مؤشر نوعية المياه.

1. INTRODUCTION

Marshes represent incubators for crucial ecosystems like fish and invertebrates, habitat for the majority of waterfowl, rice and some other crops farmland which is influenced by many natural forces and human activities also the biome mostly includes plants, and many animals, which inhabit this rich environment. Iraqi marshes are freshwater wetlands of unique ecosystem and a critical factor in the complex web of life for Shatt-Al-Arab Estuary, the Gulf, and the surrounding land ecosystems, therefore, it is important that the remaining marshes be protected and that their health enhanced wherever possible.

Iraqi marshes are considered the most extensive wetland ecosystem in the Middle East. They are located in the middle and lower basin of the Tigris and Euphrates Rivers which create a wetland network known as Mesopotamian marshes and comprise some shallow freshwater lakes that seasonally swamped floodplains. They cover about 15,000 to 20,000 km^2, extending from the region of Basra to within 150 km of Baghdad. The rainwater precipitation through the winter season in southern Turkey and Syria causes extensive flooding throughout Mesopotamia and fill up the lake system in the south, where the maximum water levels reach in early spring and then in hot dry summer fall by as two meters. Al-Hammar marsh as the largest wetlands within this complex, associated marshes in south of the Euphrates (3500 km^2); a complex of permanent lakes in the Central Marshes (3000 km^2) and marshes north of the Euphrates and west of the Tigris; Al-Hawizeh marsh associated (2200 km^2) extending east the Tigris into Iran. These wetlands eventually drain southeastward into the Gulf via the Shatt-Al-Arab Estuary. There are several factors threatening the wetlands in Iraq, which are the construction of dams on the Euphrates in Turkey and Syria, the use of marshes for water supply and agricultural purposes, and increasing utilization of Tigris and Euphrates for irrigation in Iraq have greatly reduced the seasonal flooding in these wetlands and facilitated drainage of large areas for cultivation and exploitation of oil resource, **CRIMW, 2016**. Iraqi Government and others have been taken several initiatives to restore this area, **Al-Ansari, et al., 2012.**

Al-Saad, et al., 2010 focused upon the southern marshes water quality related to the effecting physical, chemical parameters and ecological aspects. Water quality surveys were implemented during November 2005 to September 2006 at six locations, four of them in Al-Hammar marsh and two locations in Al-Hawizeh marsh. The sampling locations covered physical and chemical water quality parameters, aquatic plants and phytoplankton. Results showed some fluctuation in some water quality parameter during different seasons at different locations of the marshes also the survey established important background information and a baseline for further restoration work. **Al-Ansari, et al., 2012,** evaluated the restoring of the garden of Eden, (southern Iraq) and explored the possibilities of restoring the Iraqi marshes during 2012. The result showed that 70- 75% of the original marshes areas can be restored to achieve this goalkeeping the water quality as it is. The results also indicated that the water quality was bad and need international cooperation to overcome the existing obstacles.

Hussain, et al., 2015, studied the Iraqi marshes, Al-Hawizeh and Al-Hammar if they could act as natural filters to the Tigris and Euphrates rivers. Results showed that the water from the outlet stations became clearer, characterized by low values of BOD, nitrate, reactive phosphate, total nitrogen, ammonium, bicarbonate and high in dissolved oxygen concentrations.

The outlet waters were higher in TDS concentrations, Conductivity, Salinity, pH, Sodium, and Sulphate. Flow rate in marshes was higher in the open water than near the vegetation.
A hydrological model for water quality in Iraq marshes was developed using Landsat-TM and a hydrological model of RMA-2 with Geographic Information System (GIS), and remote sensing techniques (RST) to map the water quality in the marshlands south of Iraq, **Marghany, et al., 2016.** Results showed the water quality and quantities related to the two-dimensional water flow pattern in the marshlands through the integration between the Hydrological Model of RMA-2. Geographic Information System and remote sensing techniques can be used to monitor water quality in the marshlands south of Iraq.
This study aims to evaluate the water quality of Al-Hawizeh marsh through water quality index determinations as the physical and chemical aspects of water provide valuable indications of the overall health of the ecosystem of the marshes and the prediction of total dissolved solids (TDS) concentrations for future inspections using an artificial neural network (AAN) model.

2. MATERIAL AND METHODS
2.1 Study Area description

The Mesopotamian marshlands in Southeastern Iraq are covering more than 15,000 km^2 consist of the confluence of the Tigris and Euphrates rivers. They were reduced after 2003 to less than 7% of their 1973 levels (8,926 km^2 within Iraq). Al-Hawizeh marsh is located east of Tigris River with an approximate area of 3000 km^2, one of the major marshes in Iraq was taken a case study as shown in **Fig. 1** and **2**, **Marghany, et al., 2016.**

2.2 Data Collection and Analysis

The data used in this paper were provided from Center for restoration of Iraqi marshes and wetlands (CRIMW)/Ministry of Water Resources for the period from 2013 to 2016 which represented the monthly average values of physical and chemical natural water quality parameters including dissolved oxygen (DO), turbidity, total dissolved solids (TDS), and pH, of Al-Hawizeh marsh.

3. WATER QUALITY INDEX DETERMINATION

Water quality index (WQI) is an important technique to evaluate surface water quality human and agricultural uses which define a classification technique that provides the combined effect of various water quality parameters on the general water quality for different uses, **Rao, 2006**. The water quality index (WQI) for drinking water quality recommended by the World Health Organization, **WHO, 1998**, is calculated by equations proposed by **Tiwari and Mishra (1985)** as shown in **Table 2**, **Alsaqqar, et al., 2013** and **Khudair, 2013,** and based on the calculated WQI, the classification of water quality types is shown in **Table 3**.

$$w_i = \frac{K}{S_i}$$

(1)

$$q_i = \frac{(V_i - V_{10})}{(S_i - V_{10})} \times 100$$

(2)

$$Overall\, WQI = \sum_{i=1}^{i=n} w_i \times q_i$$

(3)

Where:

w_i: Unit weight factor;

K: Proportional constant;

S_i: Standard permissible value of i^{th} parameter.

q_i: Quality rating scale for the i^{th} water quality parameter.

V_i: Estimated permissible value of the i^{th} parameter;

V_{10}: Ideal value of the i^{th} parameter in pure water;

All the ideal values (V_{10}) are taken as zero for drinking water except for pH=7.0.

4. ARTIFICIAL NEURAL NETWORK MODEL

The artificial neural network (ANN) can be defined as a structure made up of simple, adaptive, interconnected elements arranged in layers. In general, ANN model structure consists of at least three layers input, hidden, and output layers containing artificial neurons and each node is connected in a specific layer to the other nodes in the subsequent layer, **Gurney, 1997**. The Statistical Procedure for Social Science, SPSS software, version 20 was used in this study to develop an artificial neural network (ANN) model to predict TDS concentrations. The ANN model comprised three neurons in the input layer. To build the ANN model, many run trials were performed, in each trial, the software parameters were changed as follows:

1. Selecting the percentage division of the input data into training, testing, and validation subsets.
2. Selecting the division method as to be blocked, stripped, or random.
3. Testing the appropriate number of nodes in the hidden layer.
4. Changing the learning rate and momentum factor.
5. Selection of the best ANN model according to the highest correlation coefficient between the predicted and observed output with the smallest testing error.

5. RESULTS AND DISCUSSION

5.1 Water Quality Index Assessment

Table 1 summaries the average water quality for Al-Hawizeh marsh during the period 2013-2016. The average TDS, pH, dissolved oxygen and turbidity values were exceeded the WHO limitations for drinking water standards. **Table 2** shows a calculation sample of sub-WQI during the study period which indicated that the water of Al-Hawizeh marsh was unsuitable for drinking according to **Table 3**. **Fig. 3** shows the water quality variation through the annual WQI of Al-Hawizeh marsh during the study period referring that the water is unsuitable (Class 5) for drinking in years 2013 and 2014.The quality changed to very poor (Class 4) in years 2015 and 2016 where a slight improvement in water quality as noticed as the WQI decreased to the range 200 to 300 (Class 4) which is due to increase water discharges of the marshes.

5.2 ANN Model for TDS in Al-Hawizeh Marsh

In order to predict TDS in Al-Hawizeh marsh using the artificial neural network (ANN) model by adopting different trials to make the model verification and find the best model using

SPSS program. The total input data value is 48 which is divided in to the training value is 34, testing value is 8, and holdout is 6 and the network information of three parameters against TDS, the input layer (covariate) include (DO, pH, Turbidity), the rescaling method for covariate is standardized, the hidden layer is four units, the activation function is hyperbolic.

The output layer which is the dependent variable (TDS) of activation function which is an identity with the sum of squares error for model testing was 0.046 while for training was 0.089. **Table 4** indicates the parameters estimates the bias of input layer, the constant variables of input layer, the hidden layer's bias and the parameters of output layers and the input layer is covariates, the hidden layer is hyperbolic tangent, while the output layer is identity and **Fig. 4** shows the architecture of the ANN model. The best determination coefficient with best regression equation between the TDS observed and predicated are 0.927 and y = 14.27+0.99 x as shown in **Fig. 5**, while **Fig. 6** shows the importance of the independent variable which depends on the data input of each parameter and the interaction of each parameter with the TDS parameter. The DO parameter has the highest importance of 100% because of the water in Al-Hawizeh marsh is considered as fresh water because it is refreshing from Tigris river while turbidity parameter has the lowest importance.

6. CONCLUSIONS

From this research, the following can be concluded:

1. High concentration of TDS in Al-Hawizeh marsh pose threats to the people who use the marsh for drinking and other uses.
2. Overall WQI value for Al-Hawizeh marsh indicted that the water is unusable for drinking.
3. The developed ANN model is suitable for predicting future values of TDS in Al-Hawizeh marsh with a high correlation coefficient 0. 927.
4. In the ANN model, DO parameter had the highest importance of 100%, because the water of the marsh is fresh water, while Turbidity had the lowest importance.

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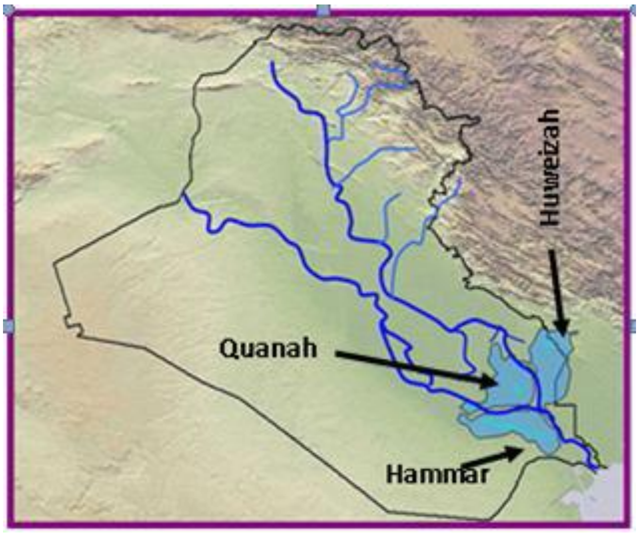

Figure 1. Marshes in the south of Iraq.

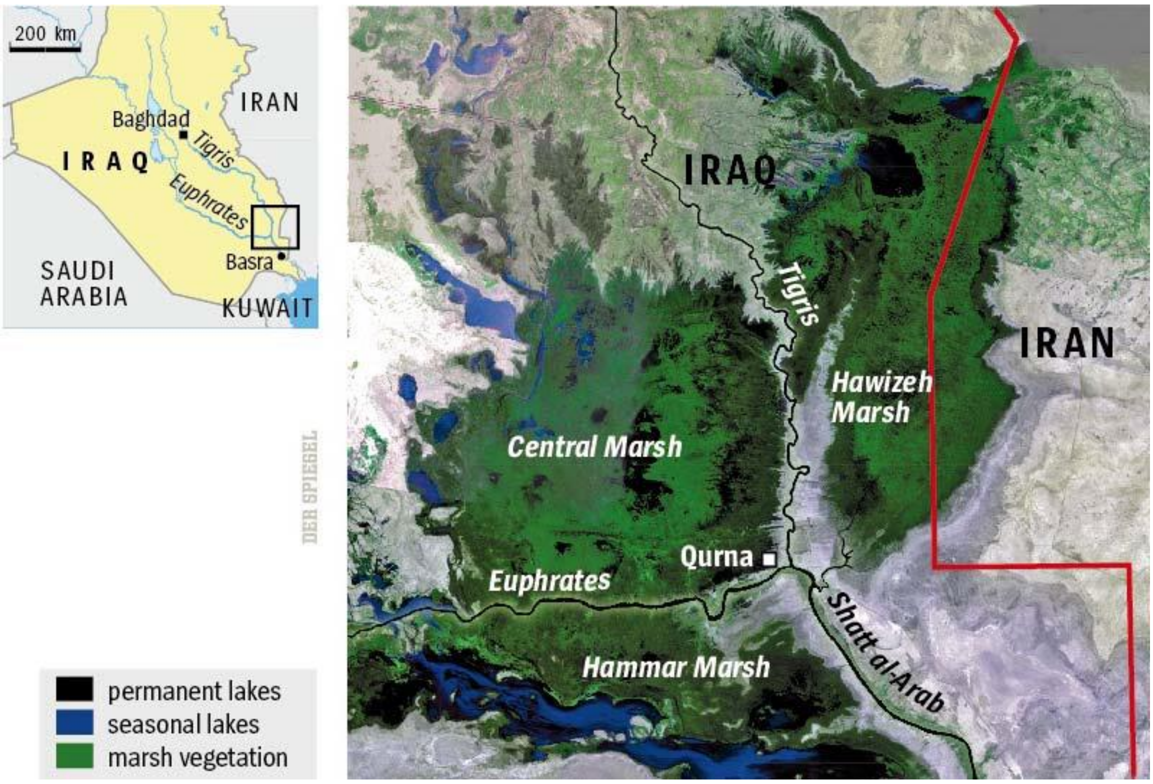

Figure 2. South of Iraq marshes.

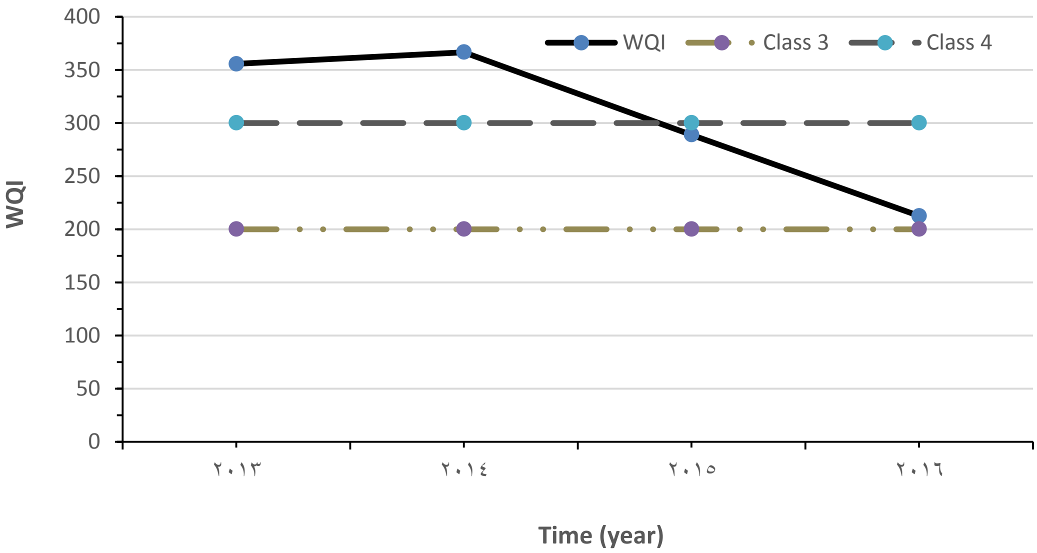

Figure 3. Annual WQI variation during the study period (2013-2016).

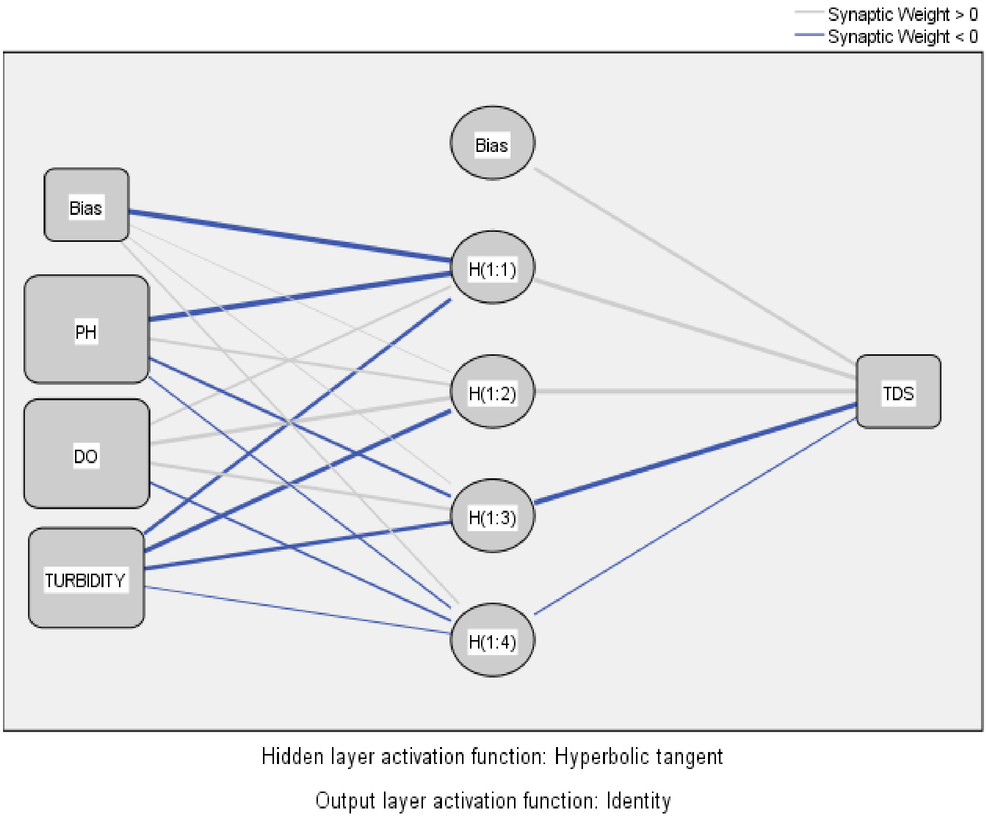

Figure 4. Architecture of the ANN model.

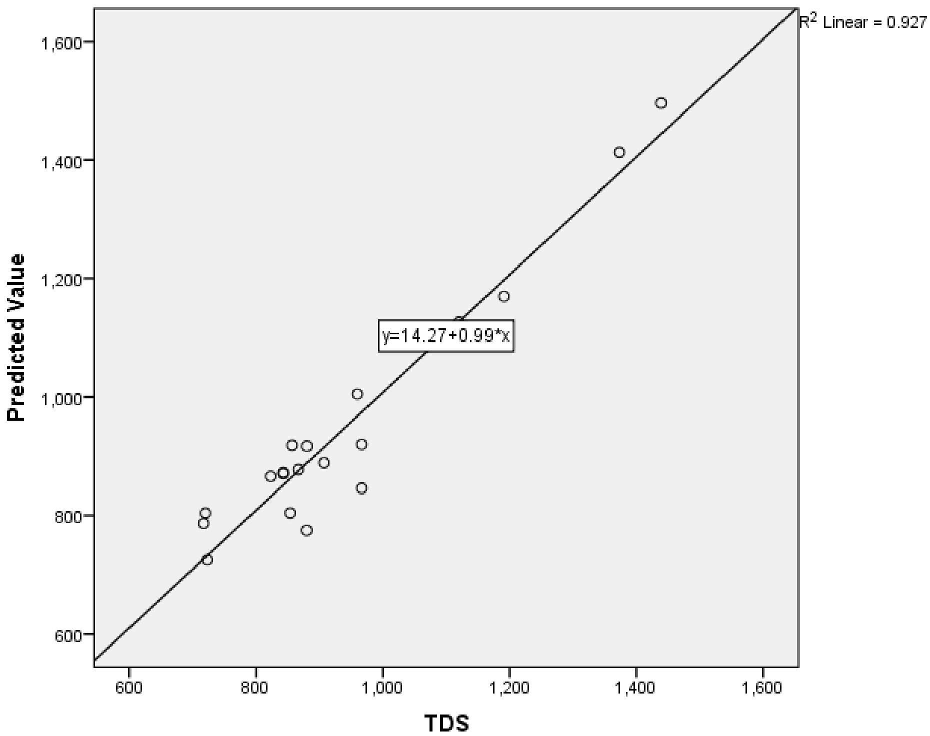

Figure 5. Predicted values versus dependent variable.

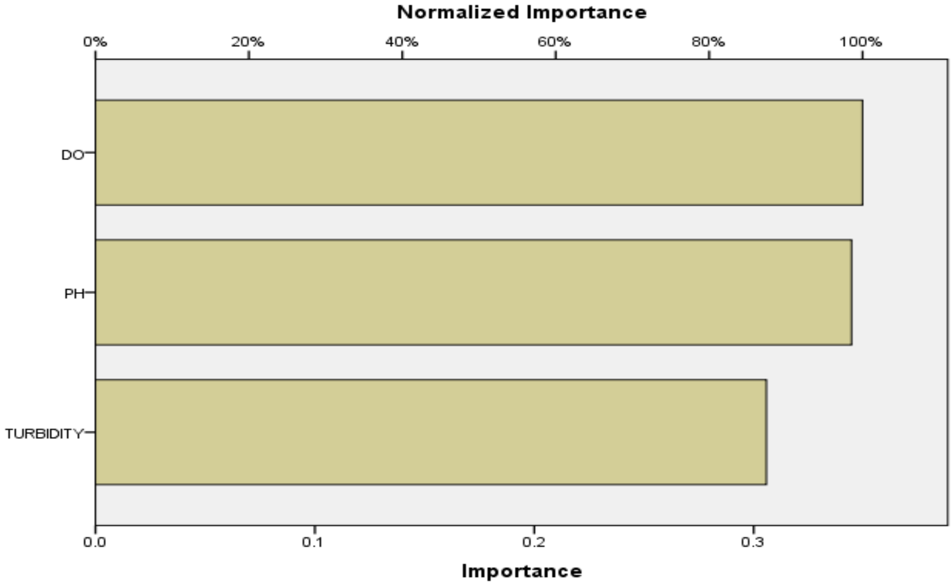

Figure 6. Independent Variable Importance.

Table 1. Water quality parameters for Al-Hawizeh marsh during (2013-2016).

Parameter	Min.	Max.	Avg.	STDEV	Skew	Kurtosis
pH	7	8.51	7.87	0.33	-0.49	0.22
TDS (mg/L)	703	2370	1101.36	360.31	1.51	2.5
DO (mg/L)	3.37	10.7	7.76	2.11	1.29	5.63
Turbidity (NTU)	0.03	47.1	8.49	10.38	2.31	5.69
WQI	103.11	1123.98	312.69	217.29	2.29	5.67

Table 2. Water quality index calculations for Al-Hawizeh marsh during (2013-2016)**.**

Test Type	Average (Ci)	Standard Value (Si)	Proportional Weight (K)	Unit Weight Factor (wi)	Quality Rating (qi)	WQI (wi*qi)
pH	7.87	7.5	4	0.286	104.933	29.981
TDS (mg/L)	1101.36	500	5	0.357	220.272	78.669
DO (mg/L)	7.76	5	2	0.143	155.200	22.171
Turbidity (NTU)	8.49	1	3	0.214	849.000	181.929
			14	1.0	1329.405	312.750
Overall WQI						312.75

Table 3. Water quality classes based on WQI value, **Amadi, et al., 2010**.

Class	WQI Value	Water quality
1	<50	Excellent
2	50-100	Good water
3	100-200	Poor water
4	200-300	Very poor water
5	>300	Water unsuitable for drinking

Table 4. Parameter Estimates.

Predictor		Predicted				
		Hidden Layer 1				Output Layer
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	TDS
Input Layer	(Bias)	-2.277-	.049	.094	.536	
	PH	-2.943-	.940	-.944-	-.394-	
	DO	.870	1.469	1.054	-.616-	
	TURBIDITY	-1.264-	-1.921-	-1.313-	-.226-	
Hidden Layer 1	(Bias)					1.206
	H(1:1)					1.793
	H(1:2)					1.925
	H(1:3)					-1.948-
	H(1:4)					-.278-