USING OF INTELLIGENT ARTIFICIAL NEURAL NETWORK PREDICTIVE MODEL FOR IRAQI MARSHES RESTORATION

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Abstract

This paper focuses one of the problems that challenges the continuation of inhabitant and aquatic organisms' life in the Mesopotamians wetlands, it is the dryness of marshes. Artificial Neural Networks (ANN) approach is applied to forecast and suggest a future release policy to restore Al-Huweizah Marsh. The suggested ANN model used to predict three different long-term (5, 10 and 15-years) policies to increase marsh water level from 2 to 7 meter above sea level. The results showed that the application of ANN for Al-Huweizah Marsh restoration using a network structure of 9:9:1 (input: hidden: output) has the ability to simulate marsh restoration process successfully with a regression coefficient of 99.8% and root mean square error of 0.88. Linear increment, high inflows months and month inflows weight restoration policies are applied to restore the marsh using each of optimistic, pessimistic and abstemious expected inflows. The ANN model and suggested policies are built in such a way to produce the same target head at the end of any year, this strategy will not cause a large variation between the resulted outflows for the suggested policies; at same time, the strategy enables the decision maker to move between policies according to the available inflows without changing the target level needed to be reached at the end of operating policy. The shortages in expected inflows to complete the suggested policies are little and may be overcame.

Keywords: ANN, Marsh restoration, Release policy, Water resources management, Inflow-outflow relationships

Introduction

The Mesopotamian Marshes locally known as "Ahwar" are a wetland area located in southern Iraq. Marshes were the cradle of the early Mesopotamian civilizations and a natural habitation for many aquatic organisms, especially fish and birds. This wetland once covered 20,000 km^2 and was the largest in the Middle-East region. Since the 1970s and up to 2003, however, over 90% of the original marshlands area were drained or destroyed due to systematic over-exploitation, political reprisals against the inhabitants, and a lack of coordinated management. Inhabitances were forced to flee and relocate throughout Iraq and beyond. For those who have stayed, many live in poor conditions significantly worse than in the rest of the southern region. Iraqis marshlands comprised of three major areas; Al-Huweizah Marsh (the marsh that focuses through this study), Al-Hammar and Central marshes (Qurnah) as shown in figure 1.

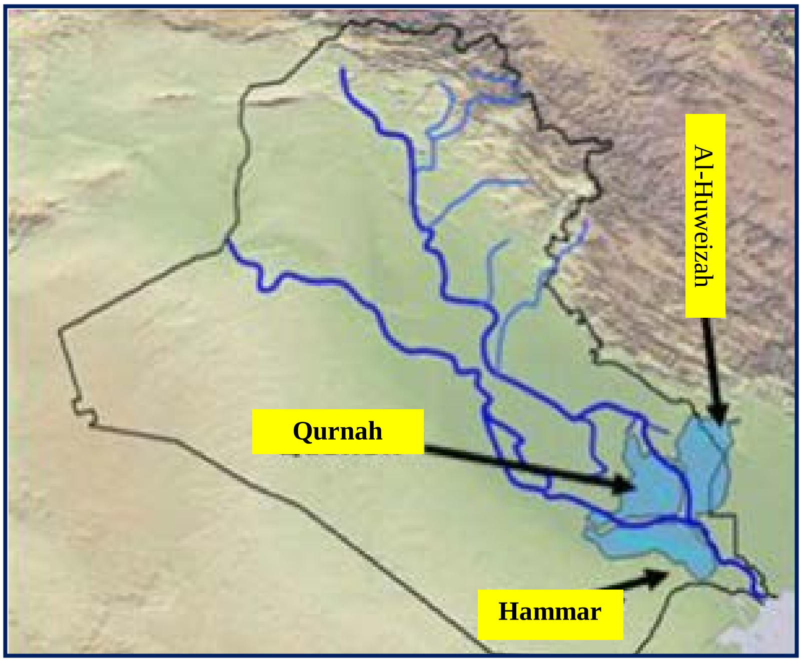


Figure 1 Major marshes in iraq.

After 2003, marshes tried to be reflooded, but an obstacle was emerged that was due to the shortage in water quantities supplied by feeders.

Many researchers, organizations and governmental efforts dealt this problem and attempted to solve it by discussing, analyzing and suggesting various operating scenarios and policies. Studies like as UNEP, 2002; Iraqi Foundation, 2003; IMET and IF-2, 2004; Italian Ministry for the Environmental and Territory and Iraqi Foundation, 2006; Iraqi Ministry of Environment, et al., 2006; CRIM, 2006; Ministry of Water Resources, Ministry of Environment, Municipalities and Public Works Iraq and Italian Ministry for the Environment, Land and Sea, 2007 can categorized into the organizational and governmental contributions that dealt with Mesopotamian Marshes drying. These articles varied between describtive, analytical, numerical to field works and studied the hydrologic and hydraulic characteristics of marsh wetlands, and sometimes suggested views and scenarios that tried to solve or even to restrict the development of marshes dryness effect on environment, inhabitants and aquatic organisms. Other studies concerned Iraqi Marshes that did by academic and interesting researchers like as Yousef, 2006; Shaimaa, 2008; Al Kafaji, 2009; Al-Thamiry, 2009; Al Kafaji, 2013; Hassani, 2014 and others. A detailed of related literatures were well stated by Hassani, 2014.

Present study with the benifit of previous veiwpoints and taking into account the limited inflows,mostly comes from Turkey and Iran, that expected to reach marshes, artificial intelligence techniques like Artificial Neural Networks (ANN) have been used to be a potential tool in the planning, operation and management of the available resources. Long-term policies that have the ability to overcome the unexpected shortage in marsh inflows are suggested throught the present study. Feed forward structure and the back propagation algorithm have been used to design and train the suggested ANN structures, the results of each suggested policy are analyzed and the limitations and objectives are discussed and compared to reach an effective releasing rule that may help in marsh restoration.

Study Area

Al-Huweizah Marsh lies in the eastern part of Tigris River and extends between Amarah and Qurnah town. It acts as a reservoir for water resources provided by Tigris tributaries and from Iranian rivers, the marsh drains the water in to the Tigris and Shatt Alarab through Al-Kassara and Assuwayb outlets (Shaima, 2008). Different estimations Al-Huweizah Marsh area are found in literature, according to the study done by Ministry of

Water Resources, 2003, the estimated area of Al-Huweizah Marsh occupies about 1500 km^2 including Assanna'f Marsh area, figure 2 shows the main inlets and outlets of Al-Huweizah Marsh.

The hydrological data records provided by Iraqi General Directorate of Water Resources Management through the years 1993 to 2005 and data presented by UNEP, January 2004, were used by CRIM, 2008 to obtain the average monthly discharges during flood , normal and dry years; the average inflows and outflows of Al-Huweizah Marsh according to CRIM, 2008 are shown in table 1. Average monthly evaporation and evatronsporation, area-elevation relationship, elevation-storage relayionship are shown infigures 3, 4 and 5, respectively.

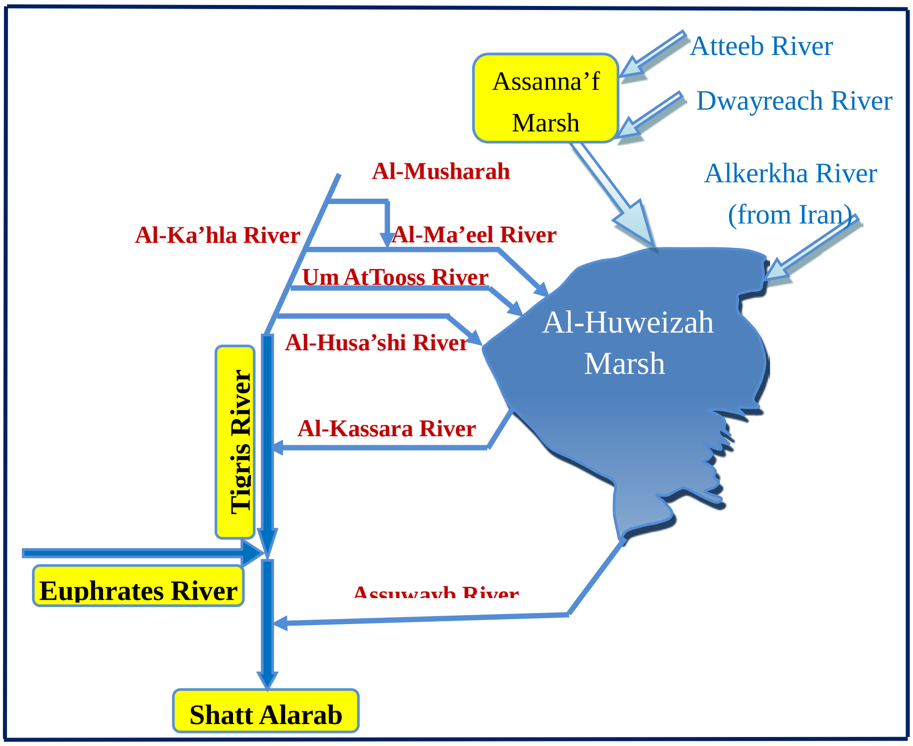
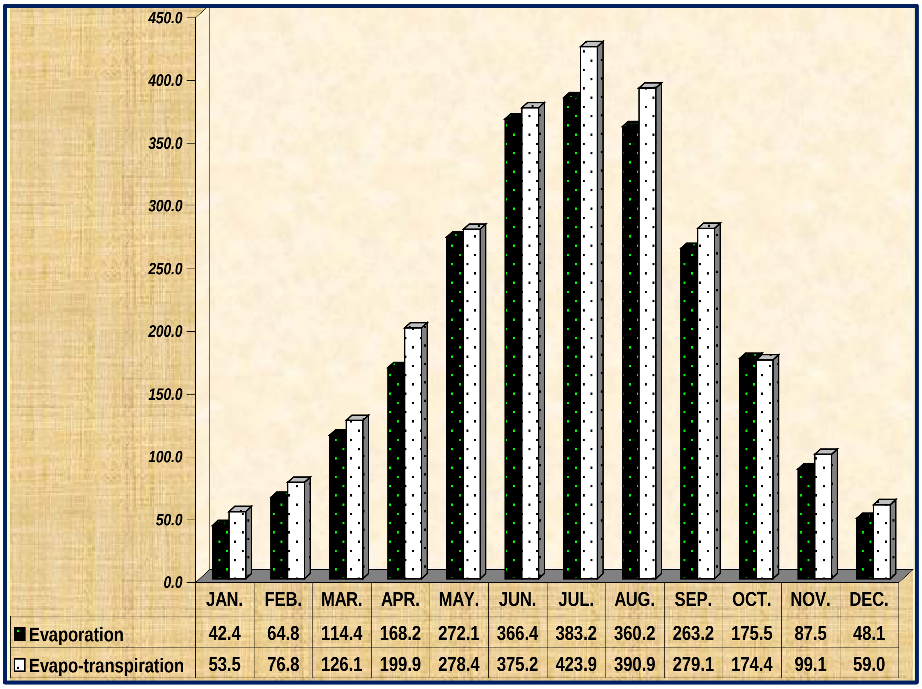


Figure 2 Main inlets and outlets of Al-Huweizah Marsh (Shaimaa, 2008 and Hassani, 2014).

Table 1 Average inflows and outflows to Al-Huweizah Marsh (CRIM, 2008)

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	may	Jun.	Jul.	Aug.	Nov.
Flood year inflow (m^3/sec)	144	206	208	494	450	443	553	373	206	143	132	130
Flood year outflow(m^3/sec)	10	15	15	20	20	20	25	89	220	220	100	10
Normal year inflow (m^3/sec)	63	84	87	289	236	218	303	211	115	82	68	64
Normal year outflow (m^3/sec)	20	0	0	0	0	0	10	80	50	30	10	10
Dry year inflow (m^3/sec)	26	26	32	34	66	114	118	85	39	30	35	32
Dry year outflow (m^3/sec)	0	0	0	0	0	0	10	20	20	20	10	10



	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
Evaporation	42.4	64.8	114.4	168.2	272.1	366.4	383.2	360.2	263.2	175.5	87.5	48.1
Evapo-transpiration	53.5	76.8	126.1	199.9	278.4	375.2	423.9	390.9	279.1	174.4	99.1	59.0

Figure 3 Average monthly evaporation and evatransporation of Al-Huweizah Marsh in mm/month (CRIM, 2008).

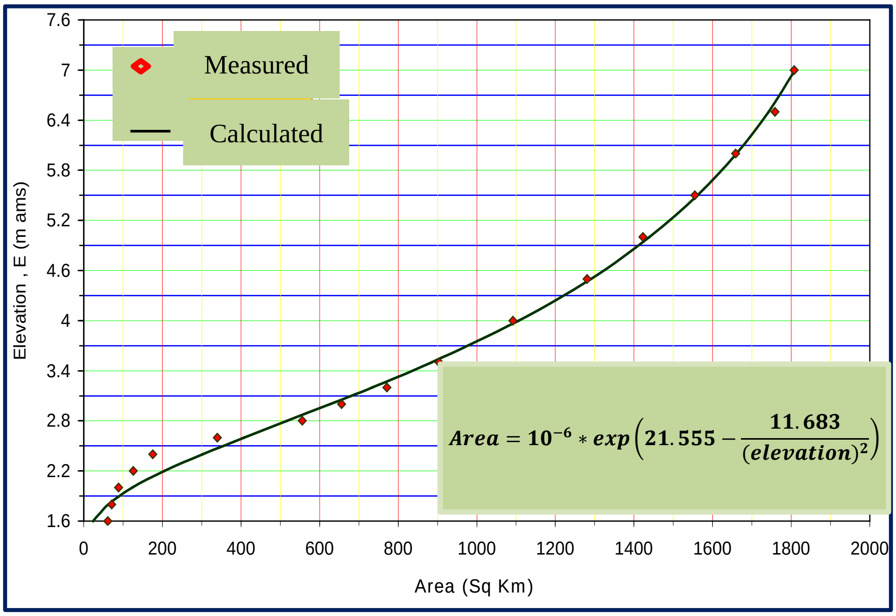


Figure 4 Area- elevation relationship of Al-Huweizah Marsh (CRIM, 2008).

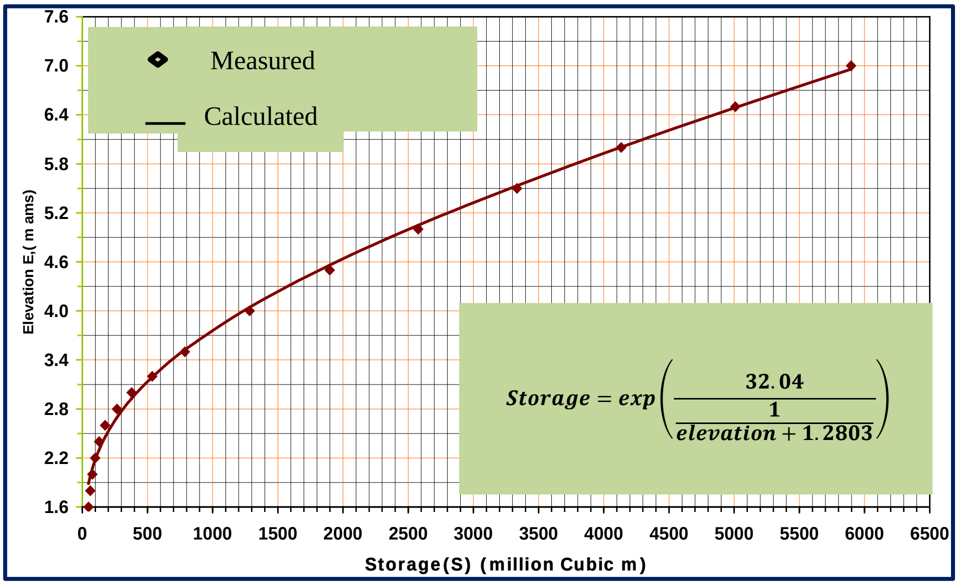


Figure 5 Elevation- storage relationship of Al-Huweizah Marsh (CRIM, 2008).

Methodology:

Artificial Neural Network (ANN) is a massively parallel-distributed-information-processing system that has certain performance characteristics resembling biological neural network of human brain. The ANN consists of a number of neurons that are arranged in an input layer, an output layer and one or more hidden layers. The input neurons receive and process the input signals and send the output to other neurons in the network where this process is continued. This type of network where information passes one way through the network is known as feed forward network. Neurons response is usually sent to the other ones (Khare and .Gajbhiye, 2013), a typical ANN structure is shown in figure 6.

These nodes specifically perform the following functions as stated by Abdulkadir and Salami, 2012:

1. Signals are received from other neurons [X_0, X_1, X_2,. *etc*.].
2. The signals are multiplied by their corresponding weights [W_0X_0, W_1X_1, … *etc*.].
3. The weighted signals are summed [$Sum= W_0 X_0 + W_1 X_1 + .$ *etc*.].
4. The calculated sum is transformed by an activation function [*f(Sum)*].
5. The transformed sum is sent to other neurons [Repeats 1-4 above].

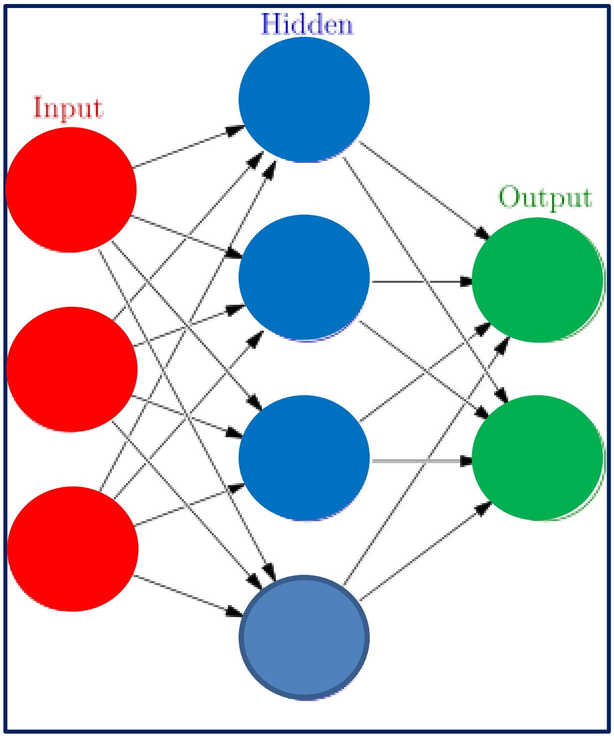


Figure 6 Typical Artificial Neural Network Structure

The input into a node or neuron is either the direct input from a sourc e exterior to the network or the weighted sum of the outputs from nodes in the layer above. Thus, the input into a node can be expressed by:

$$Net\ input\ i = \sum_{j}^{n} (Wij \times Output\ j) + \mu\ i \tag{1}$$

Where W_{ij} are the weights of node j to node i and μ is threshold function. The activation function is a crucial feature of neural nets. It limits the neuron's output to a range, usually between 0 and 1 or -1 and 1. Two functions are usually used in different applications: Sigmoid function and hyperbolic tangent; as shown in equations 2 and 3, respectively.

$$f(x) = \frac{1}{1 + e^{-x}} \tag{2}$$

$$f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \tag{3}$$

Where x is input/output of the network depending on the location wit hin the network.

Since the early 1990's, there has been a rapidly growing interest among engineers & scientist to apply ANN in diverse field of water resources engineering like forecasting of stream flows, river stage, rainfall, water table fluctuations, groundwater modelling, water quality modelling, water management, reservoir operation and so on (Khare and .Gajbhiye, 2013). Present study aims to apply the artificial neural network approach to solve a pragmatism problem that is the dryness of a large areas of wetlands, Al-Huweizah Marsh marsh is taken as a case study.

Results and Analysis

Artificial Neural Networks approach was applied to forecast and suggest a future release policy for Al-Huweizah Marsh restoration. Present study divided into two stages, the first stage was the training of the neural networks in which 7-years data that stated by CRIM, 2008 was used to train the artificial neural network model, another 8-years of marsh data was used to check the performance of the suggested ANN structures. Within this stage, the significant hidden layers number, the nodes in input and hidden layers were also tested by the mean of trial and error. The second stage included the application of succeeded ANN model to predict three different long-term policies (5, 10 and 15-years) to restore the marsh from 2 to 7 m.a.s.l., which is the storage elevation capacity of Al-Huweizah Marsh. The three polices was:

Linear increment restoration (policy-1): marsh water elevation increases linearly from 2 to 7m.a.s.l. during restoration time.

1- **High inflows months' restoration (policy-2):** marsh water elevation increases to reach the target elevation of the concerned year through high inflows months (the required increment divided equally between high flow months); inflows of other months of the year only used to maintain marsh water elevation by substituting the evaporation losses.

2- **Month inflows weight restoration (policy-3):** marsh water elevation restored monthly according to month inflow weight to reach the target elevation at the end of the concerned year, month inflow weight suggested to be calculated as:

$$MIW_t = \frac{I_{t,D} + I_{t,N} + I_{t,F}}{\sum_{t=1}^{12}(I_{t,D} + I_{t,N} + I_{t,F})} \qquad (4)$$

Where MIW_t is the inflow weight of month t and I_{tD}, $I_{t,N}$ and $I_{t,F}$ are the average inflow of month t in dry, normal and flood year. Figures 7, 8 and 9 show the suggested polices for 15, 10 and 5 years, respectively. Figures 10 and 11 explain the tested ANN structures. It can be seen from table 1, which shows a comparison between the performances of the experienced ANN structures, that the structure inputted S_{t+1}, S_{t-1}, S_t, I_{t+1}, I_{t-1}, I_t, E_t, R_t, N is the most efficient structure to predict Al-Huweizah Marsh outflows. Figure 12 shows a comparison between predicted outflows and CRIM, 2008 operating rule.

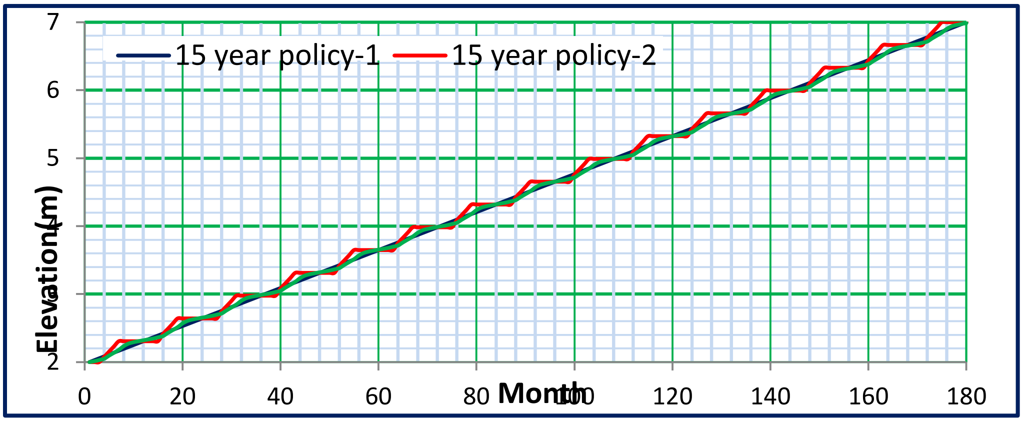


Figure 7 Suggested policies for 15 year running time.

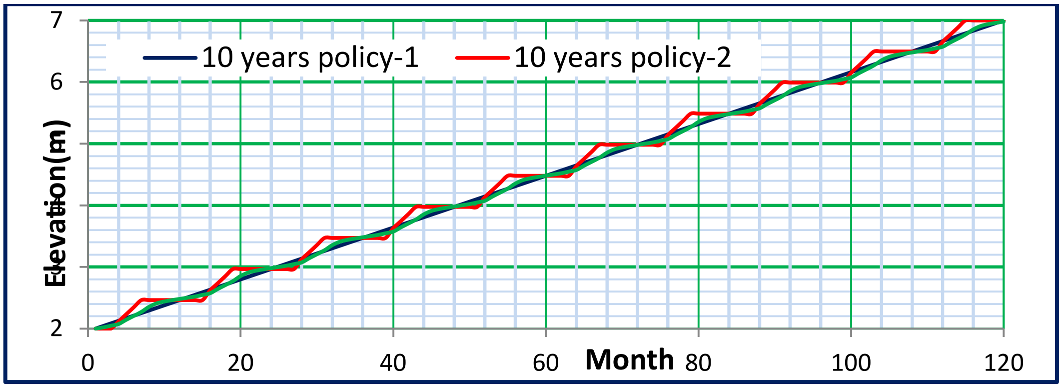


Figure 8 Suggested policies for 10 year running time.

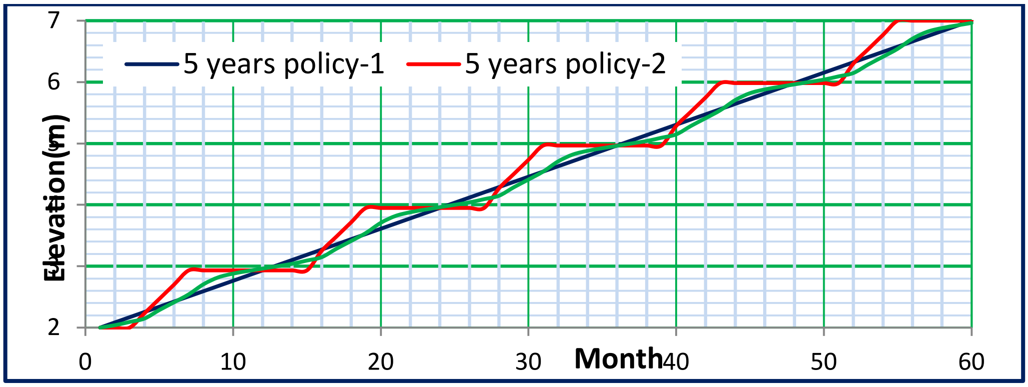


Figure 9 Suggested policies for 5 year running time.

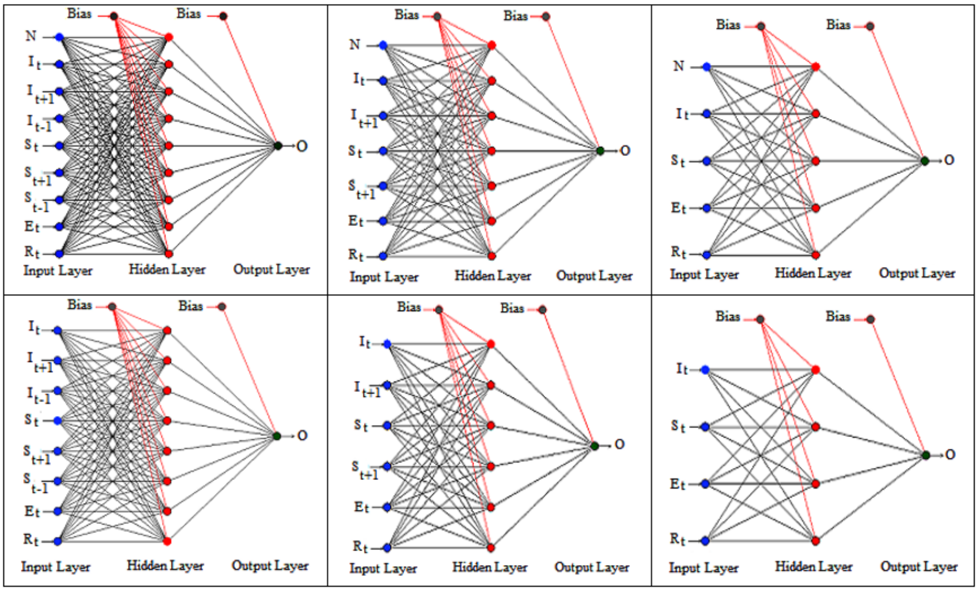


Figure 10 Tested ANN structure for Al-Huweizah Marsh restoration model.

Table 2 Studied ANN structures and their performance tests.

No.	Structure input	Number of hidden layers	Structure output	RMSE	R^2
1	N, I_t, I_{t+1}, I_{t-1}, S_t, S_t+1, S_{t-1}, E_t, R_t	9	O_t	0.879437	0.998344
2	I_t, I_{t+1}, I_{t-1}, S_t, S_{t+1}, S_{t-1}, E_t, R_t	8	O_t	2.414418	0.98752
3	N, I_t, I_{t+1}, S_t, S_{t+1}, E_t, R_t	7	O_t	3.41039	0.9751
4	I_t, I_{t+1}, S_t, S_{t+1}, E_t, R_t	6	O_t	6.136197	0.91939
5	N, I_t, S_t, E_t, R_t	5	O_t	8.141406	0.858099
6	I_t, S_t, E_t, R_t	4	O_t	4.185833	0.96249

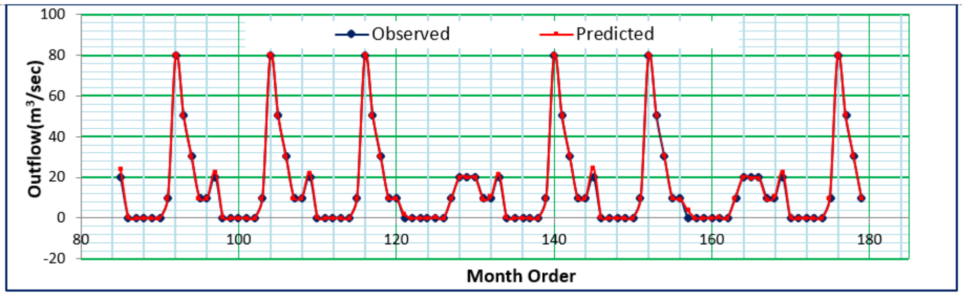


Figure 12 Comparison between CRIM, 2008 and succeed ANN structure suggested by present study.

Because of the uncertainty and poor data in the previous records of the studied marsh, three expected monthly inflows are inputted to the ANN model to predict the maximum permitted outflows from marsh that serves the suggested policies as follows:

1- **Optimistic expectation:** assuming that all years in the policy are of flood monthly inflows.

2- **Abstemious expectation:** assuming that all years in the policy are of normal monthly inflows.

3- **Pessimistic expectation:** assuming that all years in the policy are of dry monthly inflows.

Figures 13 to 21 show the operating rule that suggested for Al-Huweizah Marsh restoration using 5, 10 and 15 years' operating time for the policies shown in figures 7 to 9. The ANN model and suggested policies are built in such a way to produce the same target head at the end of any year, this strategy will not cause a large variation between the resulted outflows for the suggested policies as it clears in figures 13 to 15 (for 5-years policy), figures 16 to 18 (for 10-years policy) and figures 19 to 21 (for 15-years policy); at same time, the strategy enables the decision maker to move between policies according to the available inflows without changing the final target of marsh level needed to be reached at the end of operating policy. The shortages in expected inflows to complete the suggested policies are little and may be overtaken, as shown in table 3. The total shortage of the three suggested policies is approximately same but the number of months along which the shortage will be distributed is depended on the time period of policy. According to the releasing rule that resulted through this study, the maximum outflow was about 200 m^3/sec and Al-Huweizah Marsh has the ability to release this discharge.

Table 3: Total shortages for current study policies due to pessimistic inflows.

Policy	5-years		10-years		15-years	
	Total shortage (m^3/sec)	Number of shortage months	Total shortage (m^3/sec)	Number of shortage months	Total shortage (m^3/sec)	Number of shortage months
1	-67.6	48	-54.0	36	-58.4	16
2	-65.3	47	-53.1	36	-58.0	16
3	-66.3	47	-53.4	36	-58.1	16

Figure 13 ANN operation rule (5-years policy-1) for Al-Huweizah Marsh.

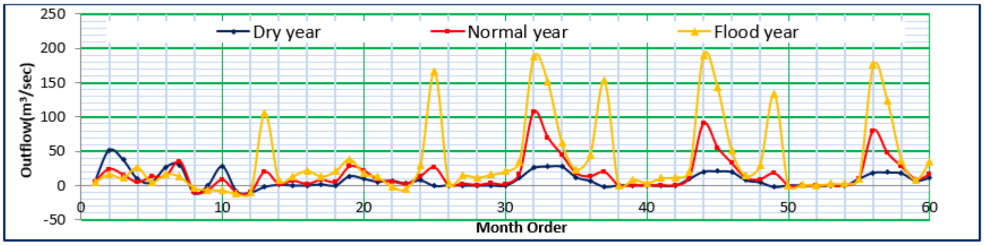


Figure 14 ANN operation rule (5-years policy-2) for Al-Huweizah Marsh.

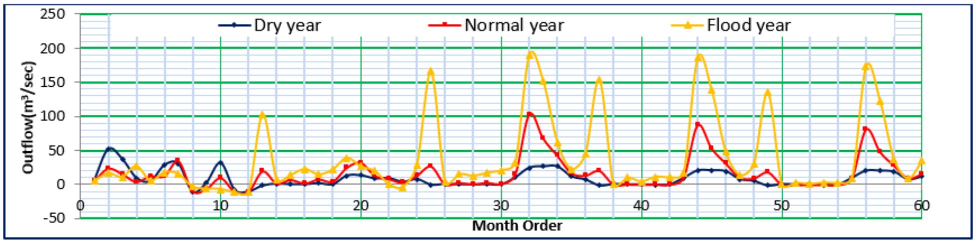
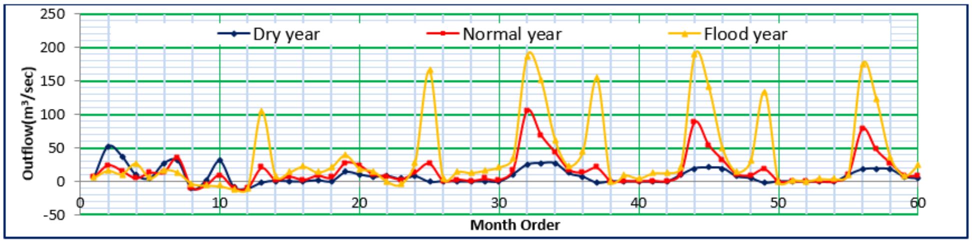


Figure 15 ANN operation rule (5-years policy-3) for Al-Huweizah Marsh.



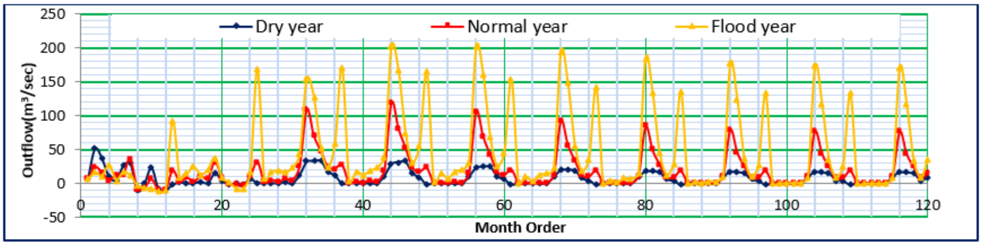


Figure 16 ANN operation rule (10-years policy-1) for Al-Huweizah Marsh.

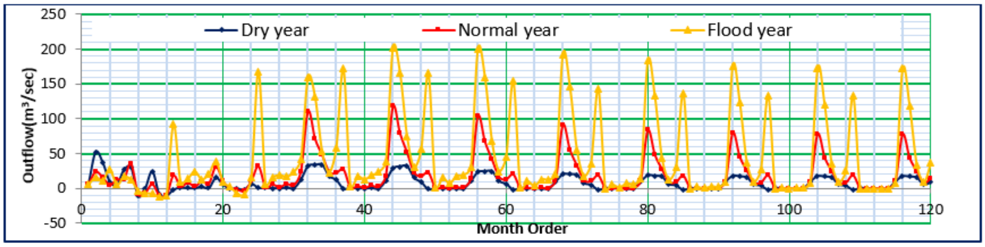


Figure 17 ANN operation rule (10-years policy-2) for Al-Huweizah Marsh.

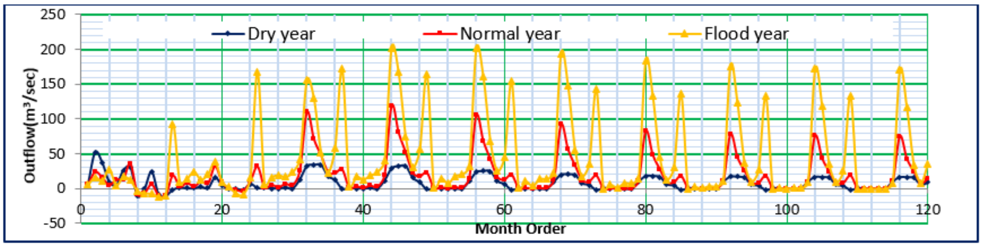


Figure 18 ANN operation rule (10-years policy-3) for Al-Huweizah Marsh.

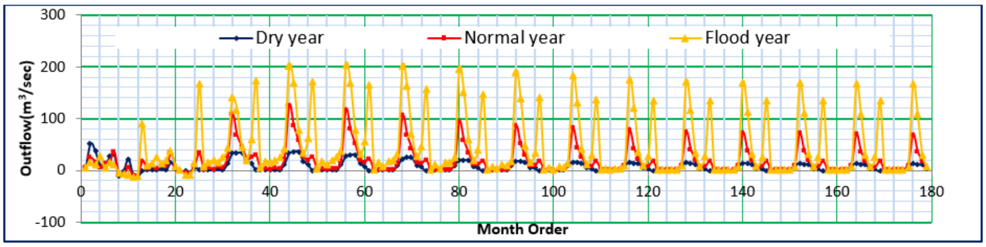


Figure 19 ANN operation rule (15-years policy-1) for Al-Huweizah Marsh.

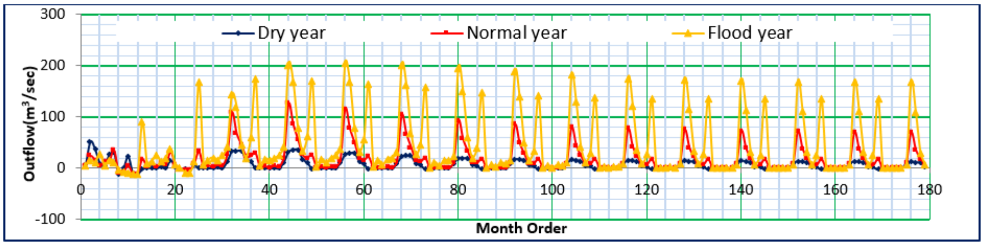


Figure 20 ANN operation rule (15-years policy-2) for Al-Huweizah Marsh.

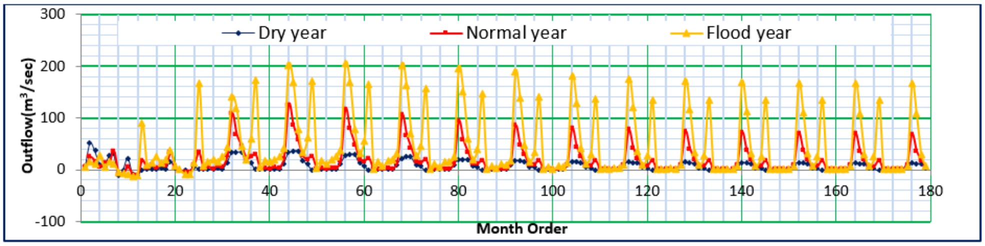


Figure 21 ANN operation rule (15-years policy-3) for Al-Huweizah Marsh.

Conclusion

Current study aimed firstly to check the performance of using ANN techniques in suggesting marsh restoration policy and secondly to predict success, flexible and applicable policy to restore Al-Huweizah Marsh. The results showed that the application of ANN in Al-Huweizah Marsh restoration using a network structure of 9:9:1 (input: hidden: output) has the ability to simulate marsh restoration process successfully with a regression coefficient of 99.8% and root mean square error of 0.88. This structure depended on the property of subsequent prediction of marsh restoration process. Because of marsh restoration is of stochastic and unpredicted circumstances, early definitive decision is difficult to be decided, so the policies suggested throughout present study and the flexibility that given to the decision maker to move from one policy to another according to the available inflows in a certain year seems to be the most suitable procedure to overcome this uncertainties.

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