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Determining the Amount of Sediment Transport of Mojen River by Artificial Neural Network and Mathematical Methods

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Introduction:

- *Accurate estimation of river load is one of the important issues in river engineering, water resources and environmental issues.*
- *Many researchers have been tried to use laboratory and field experiments for this purpose.*
- *Most of the proposed methods include complex parameters and mathematical formula.*
- *In recent years, neural solutions have been suggested for many hydrologic systems*

- **Capability of the method to relate inputs and output with acceptable error bands seems on the great advantages to use in hydrological simulation**

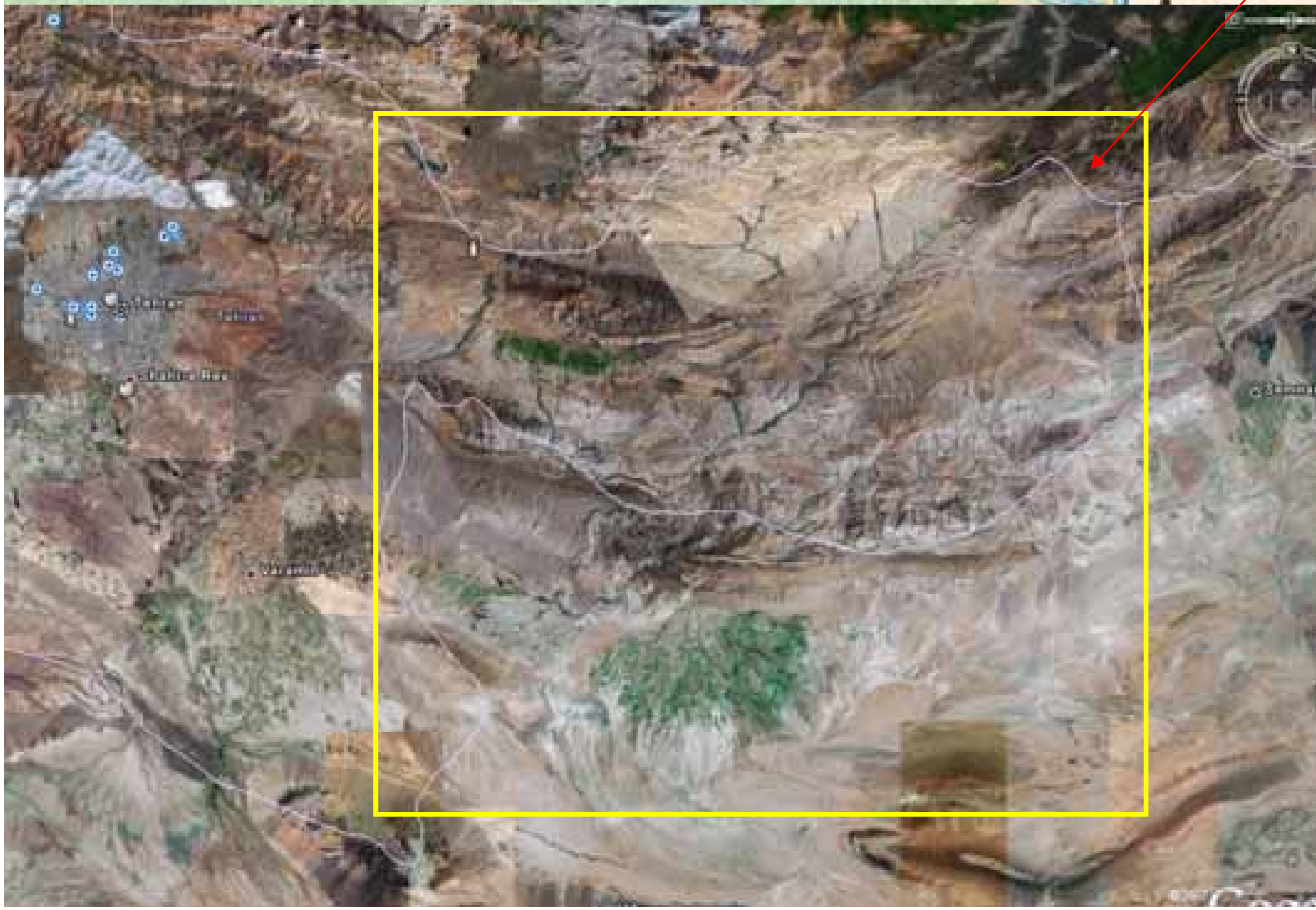
- **One of the most useful methods to cope with the nonlinearity of system is artificial neural networks(ANNs).**

- **Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth–truth values between ‘completely true’ and ‘completely false’.**
- **Fuzzy logic has emerged as a profitable tool for the control of complex processes and systems. It is used for processes that have no simple mathematical model, for highly non-linear processes.**

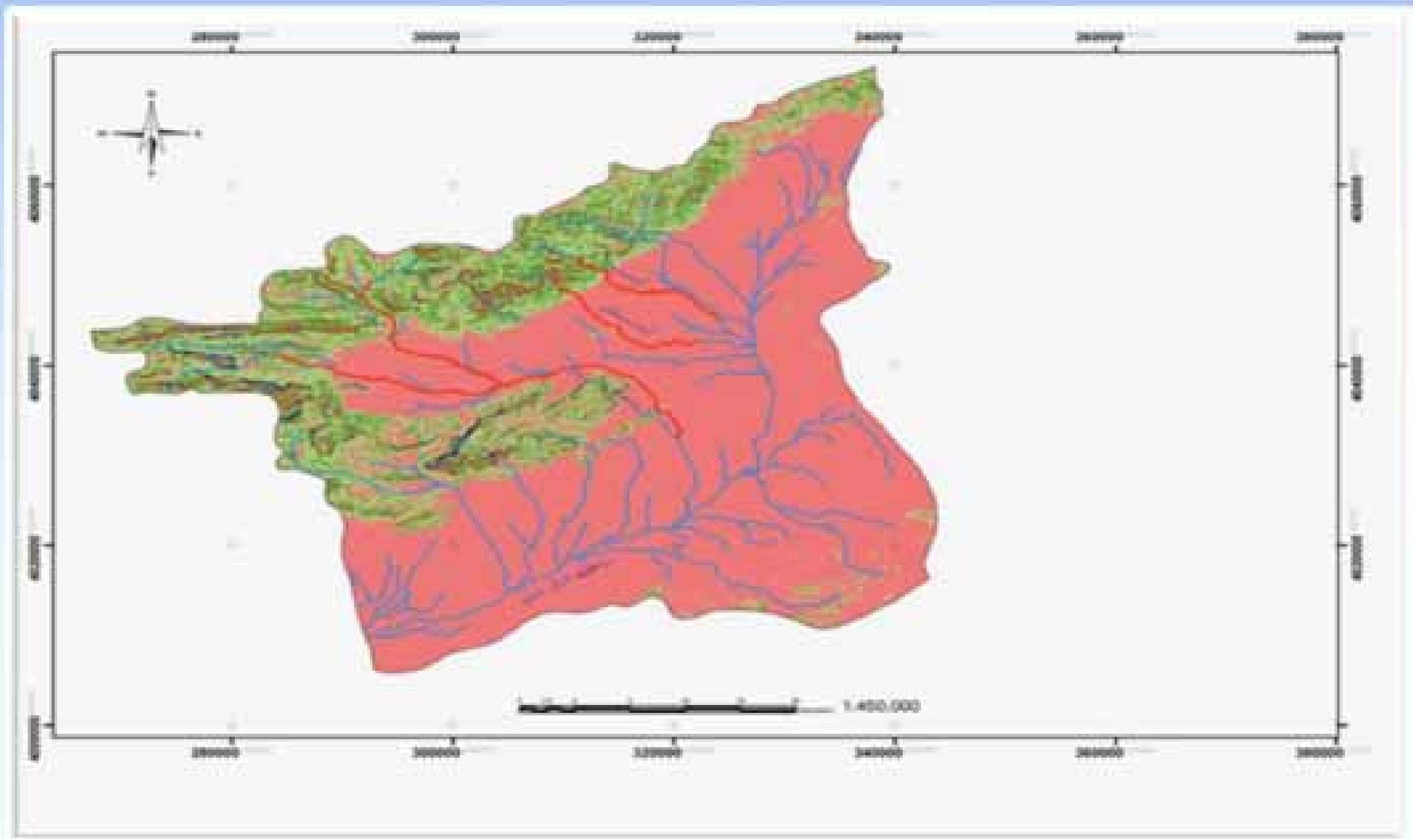
Objective

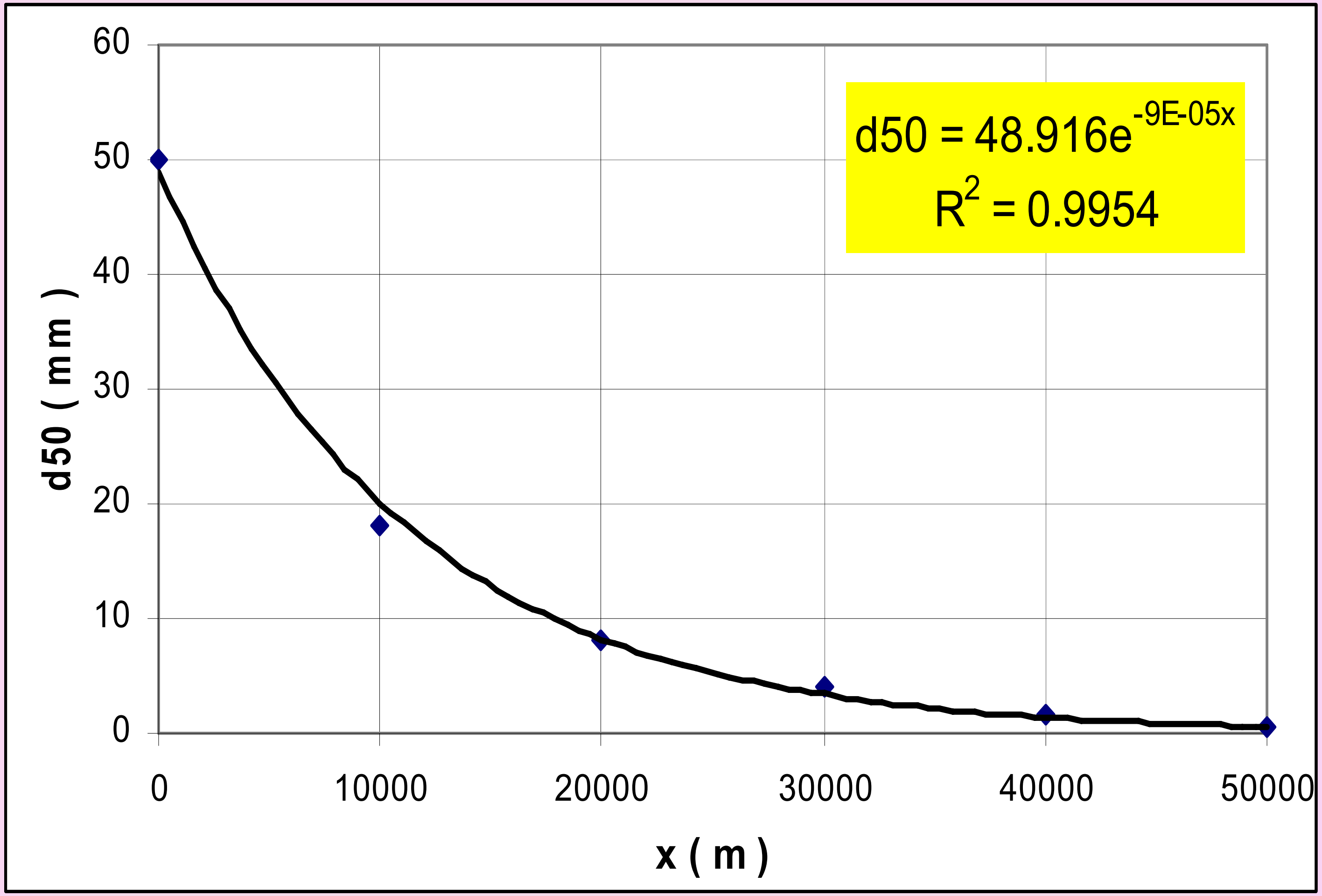
- The purpose of current research is to investigate the capability and accuracy of ANFIS and some mathematical methods for estimating river sediment load in Mojen River Basin. This region was selected because climatic factors are not the only responsible factors for sediment and river flow variation.
- Therefore ANFIS can reflect the impacts of human activities and climatic factors on sediment load in this river.

Study Region



Mojen River Basin is located in north central Iran in Semnan province. The climate is relatively cold in the uplands while dry and cold in the outlet. Long term data set including daily discharge, sediment discharge or concentration of gauging station was used in the research.





60
50
40
30
20
10
0
d50 (mm)
0
10000
20000
30000
40000
50000
x (m)
d50 = 48.916e^-9E-05x
R^2 = 0.9954

- Some field methods such as MPM (Meier-Peter-Muller), Shockleagu and Yang equations were also used for estimating river sediment.

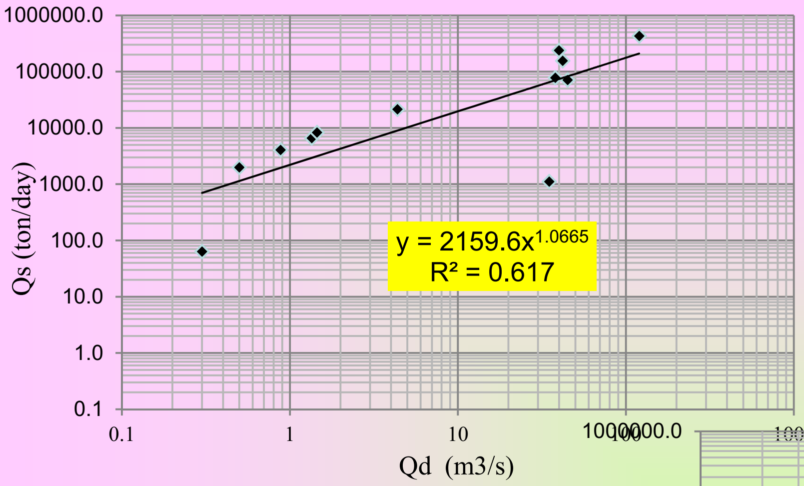
$$\frac{q_{sb}}{\left[g(G_s - 1)D^3\right]^{0.5}} = 8\left[(\mu)^{1.5} F_S - 0.047\right]^{1.5}$$

$$q_{sb} = \frac{2.5}{G_s} S^{1.5}(q - q_c)$$

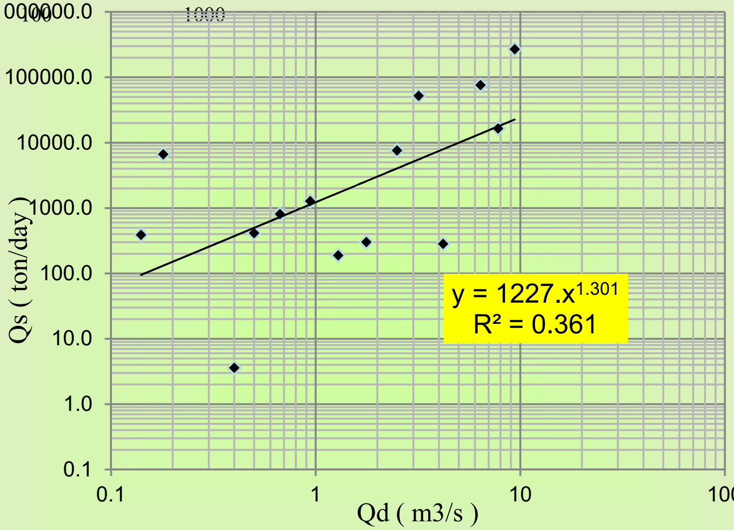
$$q_c = 0.26(G_s - 1)^{1.67} \frac{D_{40}^{1.5}}{S^{1.167}}$$

$$\log C = 5.435 - 0.286 \log \frac{wD}{v} - 0.457 \log \frac{u_*}{w}$$

$$+ ((1.799 - 0.409 \log \frac{wD}{v} - 0.314 \log \frac{u_*}{w}) \log(\frac{V.S}{w} - \frac{V_{cr}.S}{w}))$$



1000000.0
100000.0
10000.0
1000.0
100.0
10.0
1.0
0.1
Qs (ton/day)
0.1
1
10
100
1000
Qd (m3/s)
y = 2159.6x^1.0665
R² = 0.617



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Qs (ton/day)
0.1
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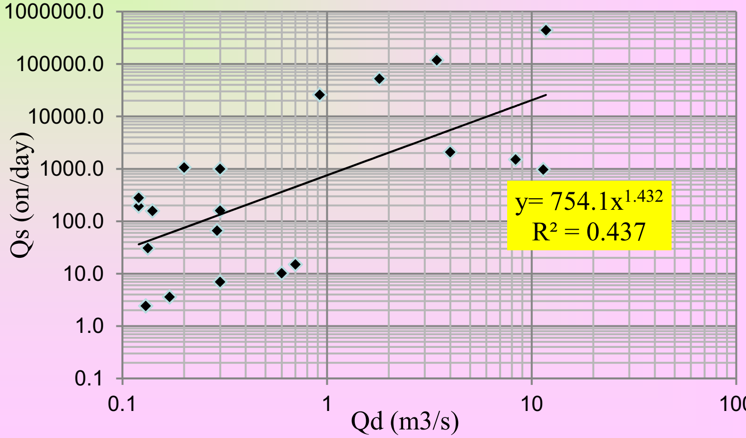
Qd (m3/s)
y = 1227.x^1.301
R² = 0.361



1000000.0
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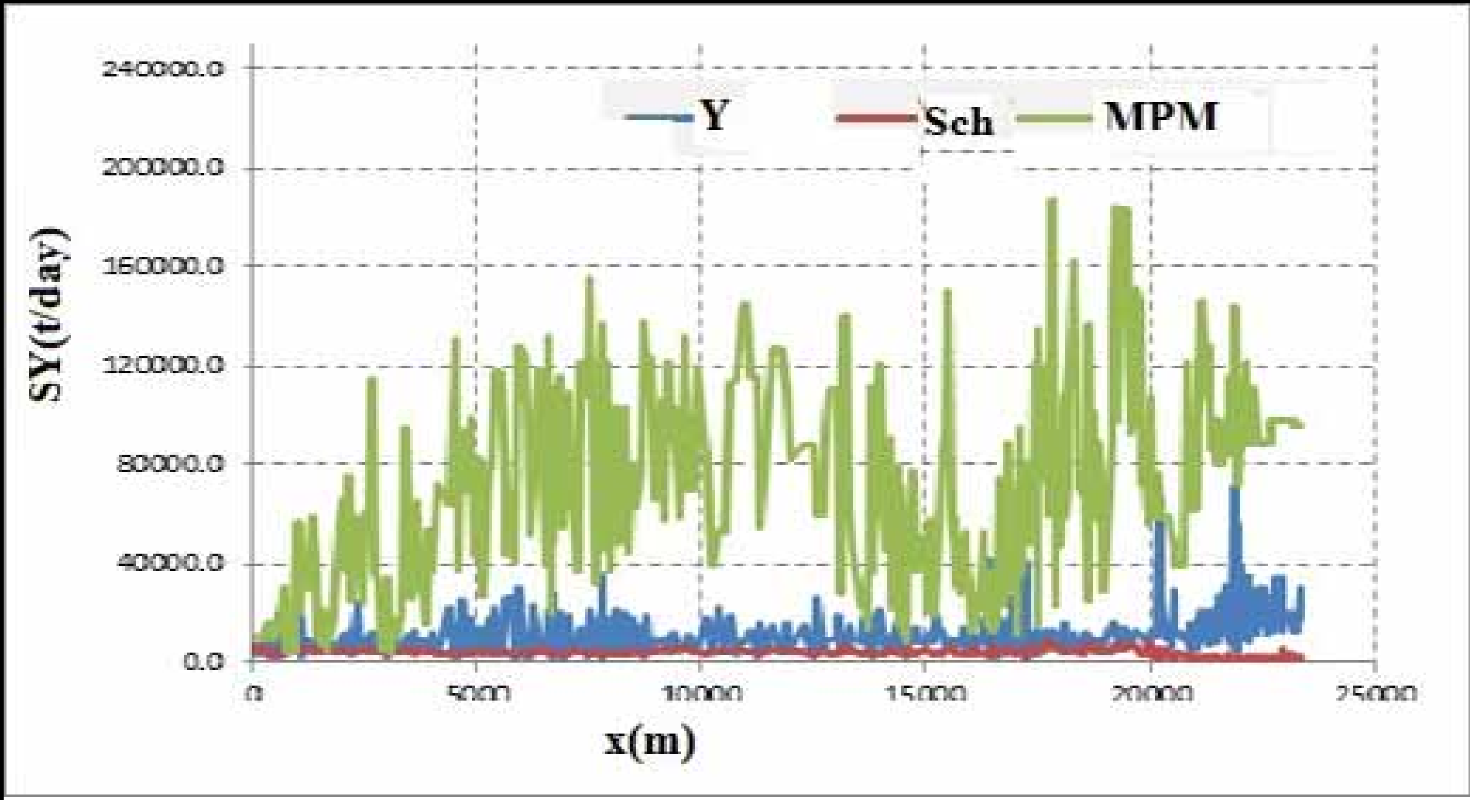
1000.0
100.0
10.0
1.0
0.1
Qs (on/day)
0.1
1
10
100
Qd (m3/s)
y= 754.1x^1.432
R² = 0.437



Y
Sch
MPM
SY(t/day)
240000.0
200000.0
160000.0
120000.0
80000.0
40000.0
0.0
0
5000
10000
15000
20000
25000
x(m)

Why ANFIS????

- ***Adaptive Network-based Fuzzy Inference System (ANFIS) allows the fuzzy systems to learn the parameters adaptively.***
- ***By using a hybrid learning algorithm, the ANFIS can construct an input-output mapping based on both human knowledge and numerical data.***
- ***The result is compared with other different algorithms. And comparing the above mentioned methods, the ANFIS algorithm gives the most accurate prediction result at the expense of the highest computation cost.***

✓ *ANFIS Model Construction in the Study Region:*

By examining the input data, the relatively inaccurate data were removed from calculations. Table 1 shows some statistical features of the data.

Table 1. A summary of some statistical characteristics of the data.

Sediment Discharge (m^3/ s)	Flow discharge (m^3/ s)	Parameter
12.27	29.19	**Max.**
2.7	5.5	**Min.**
8.99	12.85	**Mean**
24.77	**9.08**	**S.D.**

- ***The data were divided into two groups including training group (80% of data) and testing group with remaining 20% of data.***

- ***Then analysis were conducted based on premise and consequent parameters to find out the most appropriate model which optimize membership function better than other models.***

Finally three approaches including ANN, ANFIS and regression method were tested using the 20% remaining data based on the following statistical indices.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Q_{si} - \tilde{Q}_s)^2}$$

$$R^2 = 1 - \frac{\sum_{i-1}^{n}(Q_{si} - \tilde{Q}_s)^2}{\sum_{i=1}^{n}(Q_{Si} - \tilde{Q}_s)}$$

$$MAE = \frac{\sum_{i=1}^{n}\left|Q_0 - Q_e\right|}{n}$$

➢ Results

The results of optimized ANFIS and ANN techniques for the study region are shown in Tables 2 and 3.

Table 2. Characteristics of the selected ANFIS model in the region

Number of Mfs	5
Epoch	210
Mf Type	Gbell Mf
Optimum Method	Back propagation
And Method	Prod
Or Method	Probor
Defuzz Method	Wtaver

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Table 3. Characteristics of the optimized ANN model in the region

Number of neurons in input layer	1
Number of neurons in first hidden layer	10
Number of neurons in second hidden layer	2
Number of neurons in third hidden layer	0
Number of neurons in output layer	1
Activation function	Sigmoid
Rate of learning	0.01
Algorithm	Back propagation
Iteration	2500

Table 4. The result of statistical comparison between methods

Model	RMSE	MAE	R^2
ANFIS	30.45	21.97	0.978
ANN	51.3	31.16	0.96
MR	98.4	52.85	0.81

❑ Conclusion

Application of methods such as Artificial Neural Networks and Fuzzy Logic for modeling nonlinear and uncertain systems is considered by hydrologists in recent years.

Neuro-Fuzzy approach incorporates capabilities of both Artificial Neural Networks and Fuzzy Logic and then reflect more accurate predictions of the system.

Further advantageous of ANFIS is that it does not require trial and error process to find the optimum structure if network but it is needed in ANN technique.

Improved learning for ANFIS learning in this research which used 210 Epoch while in ANN, about 2500 Epoch are needed which shows higher capability if ANFIS approach.

Second order of accuracy of the results provided by ANN compared to regression model.

ANFIS results were relatively similar to the results provided by MPM approach.

HOWEVER, we need more sampling data and gaging site to exactly tell that our results exactly describes the complexity of the sediment delivery process of the rivers.


Thank You
Very Much