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Estimation of Roughness Coefficient in Erodible Channels by ANNs and the ANFIS Methods

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ABSTRACT: Estimating the roughness coefficient of erodible open channels plays an important role in their hydraulic design. This parameter also is important for the development of numerical models. For this reason, several empirical methods have been presented so far to estimate the roughness coefficient, while these methods are not sufficiently accurate. In this paper, the so-called Artificial Neural Networks (ANNs) and Adaptive Network-Based Fuzzy Inference System (ANFIS) methods as soft computing methods are used to estimate the roughness coefficient in erodible open channels. To achieve this, none-dimensional water depth with sediment particle averaged size (h/d_{50}), shear Reynolds numbers (R_*), Sheilds parameter (θ), and none-dimensional sediment falling velocity with shear velocity (w/U_f) in channel obtained by Buckingham dimensional analysis are considered as input variables. Final results show ANFIS $(R^2 = 0.8433)$ and ANNs $(R^2 = 0.8515)$ model performance in comparison to empirical methods and regression-based methods like Multilinear regression and multi nonlinear regression methods to estimate the roughness coefficient. Evaluation of the input variables' effectiveness on the coefficient via a sensitivity analysis versus the variation of error estimation by elimination of variables shows effectiveness of variables like shear Reynolds number and none-dimensional water depth usually ignored in empirical methods. The final results showed that due to complicity of sediment transport mechanism in erodible channels, models developed here can be a suitable alternative to estimate roughness coefficient.

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1- INTRODUCTION

Estimation of the roughness coefficient is an important issue for cost-effective hydraulic design of erodible channels. Also, accurate estimation of this parameter is essential for numerical modeling of fluid flow in the open channels. To do so, many experimental attempts have been dedicated to achieve some representative empirical formulas for estimation of the roughness. These formulas are commonly extracted based on fitting a function between the roughness coefficient and its effective variables (Sumer et al., 1996). Evaluation of these techniques in various conditions convinces their deficiency to estimate the coefficient in different conditions. This issue might go back to the different hydraulic conditions leading to user's confusion. Inaccurate estimation of the coefficient either may lead to the none-economical design of channels or their inefficient dimensions. Despite the importance of accurate estimation of the coefficient, researchers have never agreed on a union formula. In other words, numerous researchers have introduced various formulas to estimate the roughness coefficient. The main objective of this paper is the application of the Artificial Neural Networks (ANNs) and Adaptive Network-Based Fuzzy Inference System (ANFIS) features as implicit function approximators to find relationships among effective input variables and the roughness coefficient as the output variable. These approaches have been previously used by many researchers to predict some hydraulic processes. In recent years, the soft computing-based approaches such as Artificial Neural Networks (ANNs) and Fuzzy Inference Systems (FISs), Genetic Programming (GP), Support Vector Machines (SVMs) and so on are used to predict complex phenomena or to estimate functions representing a complex physical process. In the field of scour around pipelines and bridge piers Kazeminezhad et al. (2010) used ANN to estimate scour around marine pipelines induced by waves [1]. Zanganeh et al. (2011) employed a PSO-FIS-PSO model to estimate the equilibrium depth of scouring beneath pipelines imposed by uni-direction currents [2].

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2- METHODOLOGY

Due to the complicity of flow field and sediment transport in erodible channels and also ignoring many important parameters on channel roughness in the previous works, in this paper, new models are attempted to be developed for estimation of the parameter by ANNs and ANFIS models. To achieve this, a function representing the relationship among effective parameters on roughness coefficient is defined as follows:

$$Z(k_s, d_{50}, h, w, \rho_s, \rho_f, U_f, g, \mu_f) = 0 \quad (1)$$

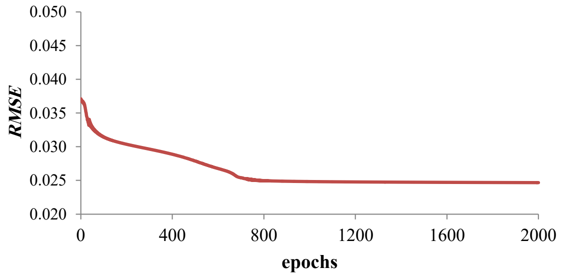

Fig. 1. the training process in the ANFIS model by normalized data (ANFISN)

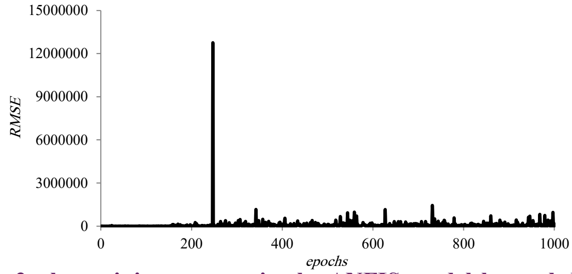

Fig. 2. the training process in the ANFIS model by real data (ANFISR)

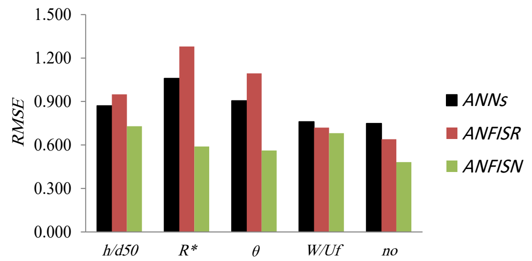

Fig. 3. Effect of input variables elimination in the training process errors

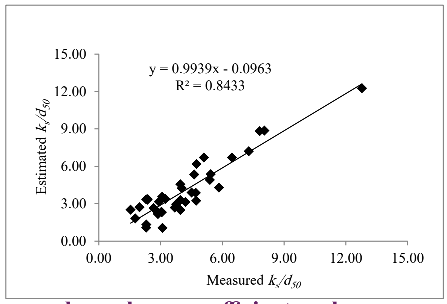

Fig. 4. Measured roughness coefficients values versus estimated ones by ANFIS

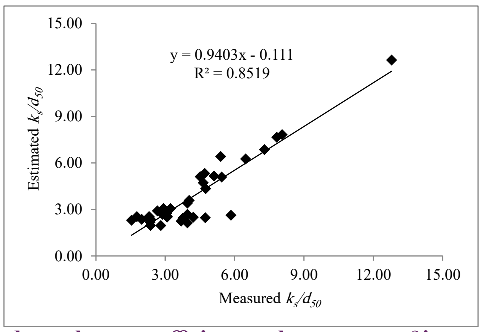

Fig. 5. Measured roughness coefficients values versus estimated ones by ANN

in which Z is a function, k_s is roughness coefficient, d_{50} is average particle size, h is water depth, w is fall velocity, ρ_s is sediment density, ρ_f is fluid density, U_f is shear velocity, g is gravitational acceleration, and μ_f is dynamic viscosity.

Using Buckingham theorem, the non-dimensional form of the equation to estimate the roughness coefficient can be extracted as follows:\

$$\frac{k_s}{d_{50}} = f\left(h / d_{50}, R_*, \theta, w/U_f\right) \tag{2}$$

in which f is a none-dimensional function that can either be an implicit function like the ANFIS -based model or ANNs. R_* is shear Reynolds number and θ is Shield's parameter.

3- RESULTS AND DISCUSSION

To develop ANNs and ANFIS selected data sets from Summer et al. (1996) work [3] categorized as the training, validation and testing data sets have been selected randomly in order to have models with acceptable generalization capability. From 158 data points gathered by Summer et al. (1996) 100 data points are chosen randomly as training data points, 18 data points are used as validation data points, and the remaining 40 data points are used as the testing data.

After selection of the ANFIS and ANNs parameters, the training process of the ANFIS models for both models trained by real (ANFISR) and normalized (ANFISN) data for estimating the roughness coefficient are shown in Figures 1 and 2. Decreasing trend of the RMSEs for training data sets error in the ANFISN reassures either fair selection of input variables or fuzzy IF-THEN rules parameters. As it is apparent from Figure 2 in the ANFISR the errors associated with the training is high. These errors prove the ANFISN model performance in comparison with the ANFISR model from an error estimation viewpoint. Evaluation of the input variables effectiveness on the coefficient via a sensitivity analysis versus the variation of error estimation by elimination of variables shows effectiveness of variables like shear Reynolds number and none-dimensional water depth usually ignored in empirical methods as shown in Figure 3. However, evaluation

Table 1. Statistical characteristics of the models

Index	Wilson (1989)	Sumer et al. (1996)	Yalin (1992)	MNLR	MLR
Bias	2.95	3.35	-0.549	-0.523	1.321
RMSE	3.46	1.75	1.531	1.898	2.330
R^2	0.5354	0.4863	0.6286	0.4662	0.5226

versus testing data, as shown in Figures 4 and 5 and Table 1, proves ANN model superiority against empirical models and multi-regression methods.

4- CONCLUSIONS

In this paper, so-called ANFIS and ANNs model and Multi Regression (MR) methods are employed to extract implicit relationships among the roughness coefficient and input variables involved in estimating the coefficient. Besides, conventional empirical formulas are implemented to evaluate the models. Results show that the employed methods are more accurate than empirical methods while other parameters like none-dimensional water depth and shear Reynolds number are recognized as effective variables on the roughness coefficient.

REFERENCES

[1] Kazeminezhad, M. H., Etemad-Shahidi, A., & Bakhtiary, A. Y. (2010). »An alternative approach for investigation of the wave-induced scour around pipelines«. Journal of Hydroinformatics, 12(1), 51-65.

[2] Zanganeh, M., Yeganeh-Bakhtiary, A., & Bakhtyar, R. (2011). Combined particle swarm optimization and fuzzy inference system model for estimation of current-induced scour beneath marine pipelines. Journal of Hydroinformatics, 13(3), 558-573.

[3] Sumer, B. M., Kozakiewicz, A., Fredsøe, J., & Deigaard, R. (1996). »Velocity and concentration profiles in sheet-flow layer of movable bed«. Journal of Hydraulic Engineering, 122(10), 549-558.

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