

# ANN-based sediment yield models for Vamsadhara river basin (India)

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## Abstract

Most universally accepted feed-forward error back-propagation artificial neural network models, supported by batch- and pattern-learning, daily, weekly, ten-daily and monthly sediment yield were developed for the Vamsadhara River basin of India. The fast gradient descent optimisation technique improved with variable learning rate ( $\alpha$ ) and momentum term ( $\beta$ ) was used for optimisation. In the process of optimisation and updating of weights, criteria adopted to terminate the process of learning was selected as a pre-decided high number of iteration and the other is the generalisation of model through cross-validation. In all cases of model formulation, the data were normalised with the maximum value of the variable of the series individually. The pattern-learned models were found superior to batch-learned models. High numbers of iterations adopted for model development were found to reduce the value of the objective function, but with model's over-learning and that is reflected? Unclear what is meant by an increase and decrease of the performance in calibration and cross-validation, respectively. The generalised pattern-learned models for different time scales were compared with linear transfer function models and it was found that the pattern-learned models developed with generalisation through cross-validation were superior in general, except weekly for the study area.

**Keywords:** back propagation artificial neural network, sediment yield modelling, generalised modelling.

## Introduction

Since the 1930s, numerous linear and non-linear hydrological models have been developed to simulate and forecast various hydrological processes and variables. The suggested models have continuously been improved by introducing new tools to effectively simulate the processes. The developed models in the area of hydrology can broadly be classified into regression models, stochastic models, conceptual or parametric models and system models.

Regression models are either regression or correlation based, and correlate the input(s) and output(s) of a process in the form of linear or non-linear relationship, which estimate the constants of regression models. Few universally acceptable hydrological models that have been developed in this category are the USLE, MUSLE and Elwell models. The stochastic models normally extract the statistical properties of time series and propagate these properties during prediction. Such models normally require a long time series and their extrapolation properties are poor. Some of the widely used stochastic models in hydrological studies are auto-regressive, auto-regressive moving average, auto-regressive integrated moving average, seasonal auto-regressive integrated moving average, etc. The conceptual models are designed to approximate within their structure the general internal physical subprocesses. The models usually incorporate simplified forms of physical laws or a series of physical laws to represent the transformation of input to output. These laws are generally linear or non-linear, time variant or time invariant, lumped or distributed, casual or non-casual and dynamic or memory less. Among the most widely used conceptual models in the field of hydrology are the Sacramento Soil Moisture Accounting (SAS-

SMA) model of the U.S. National Weather Service, HEC of U.S. Army Corps of Engineers and the Stanford Watershed Model and System Hydrologic European (SHE) model.

Artificial neural network (ANN) is a new soft computing technique composed of densely interconnected processing nodes which has the ability to extract and store the information from the few patterns (data) in training through learning. ANN architecture parallels in processing with that designed to process the information in neuro-computing (Vemuri, 1992). The model is easy to develop; yields satisfactory results when applied to complex systems poorly defined or implicitly understood; and more tolerant to variable, incomplete or ambiguous input data. Hydrologic applications of ANN include the modelling of daily rainfall-runoff-sediment yield process, snow-rainfall process, assessment of stream's ecological and hydrological responses to climate change, rainfall-runoff forecasting, ground water quality prediction and ground water remediation. ASCE (2000a;b), Jagadeesh (2000), Tokar (2000), Rajurkar (2002) among others provided a good overview of the ANN application to rainfall-runoff simulation and prediction. Imrie (2000) improved the generalisation by adding a guidance system to the cascade correlation learning architecture and extrapolation properties using an activation function. Wilby (2003) was able to interpret the internal behaviour of an ANN-based rainfall-runoff model. To this end, he deleted all the nodes other than the hidden nodes and compared with the state variables and internal fluxes. Danh (1999) and Elshorbagy (2000) proposed feed-forward error back-propagation artificial neural network (BPANN) models for runoff forecasting using fixed stopping criterion and independent variables, respectively, and compared them for performance with the available conceptual models. The works of Thirumalaiah (2000), Xu (2002), Birikundavyi (2002), Shivakumar (2002), Cigizoglu (2003), and Xiong (2002) among others are notable for real time forecasting of runoff. Other ANN applications include derivation of unit hydrograph (Lange, 1998). Only a few studies (Tayfur, 2002; Nagy, 2002; Cigizoglu

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