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Hydrological Data Network Modelling using Artificial Neural Network in Betwa Catchment

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Abstract— Design of hydrological data network depends not only on physical parameters but also uncertainty in volume and flow of rainfall and runoff. Bias in uncertainty level can't be removed fully, hence use of artificial neural network (ANN) based on training of past dataset can provide useful insight in determination of optimal network. In this paper, an attempt has been made to use the power of soft computing in terms of ANN based analysis of rainfall data of Betwa river catchment. Genetic feed forward algorithm and sensitivity analysis of mean data was done in EXCEL based version of NeuroSolution Software. Minimum spatial error in rainfall values of catchment provided clues about location of stations.

Key words — Spatial error, sensitivity, hydrological data network, uncertainty in rainfall

I. INTRODUCTION

Use of network theory in designing optimum route of connectivity among different sites and areal representation of various alternatives has now advanced to the stage of its theoretical simulations using artificial neural network (ANN). This concept of artificial network, similar to that of sending responses to brain through neurons in human body system, can now be applied to site network design and its feasibility/optimality can be seen on computer screen which can, then, be used for prediction of natural impacts on network. It was earlier demonstrated for water quality parameters [1]. The recent studies regarding optimum analysis of hydrological data network have been extended to groundwater regime also. Various genetic algorithms have been devised to the multi-objective groundwater-monitoring problem [2]. Water supply network has also been studied in order to make it more efficient, economic and rational [3].

II. STUDY AREA

The catchment area of Betwa river, a geologically and historically strategic region in central India, is marked by diverse hydrological and physiographic characteristics, is selected for the case study. The catchment area is bounded by northern alluvial plains and southern Vindhyan plateau. It extends from 22°20' North to 26°0' North latitudes and 77°10' East to 80°20' East longitudes and covers (including parts) four districts of southern Uttar Pradesh (Jalaun, Hamirpur, Jhansi and Lalitpur) and ten districts of Madhya Pradesh (Datia, Shivpuri, Guna, Tikamgarh, Chhatarpur, Sagar, Vidisha,. Bhopal, Sehore and Raisen).

The catchment area, under the jurisdiction of Uttar Pradesh and Madhya Pradesh, suffers from uneven agricultural and irrigational developments. Presumably, it has been affected by the spatial network of hydrological data also. Reference [4] shows that fertile alluvial plains in the north coupled with irregular famines have resulted in great demand for more accurate measurements of rainfall and thereby, maximum number of rain-gauging stations were established here during the British time period. Problems like soil erosion in the ravenous belt and large-scale silting of its largest reservoir, *i.e.* Matalila, can be better monitored if a scientific assessment of data record is made. Most of the studies in the region like that of Indo-British project on surface hydrology of the upper Betwa basin, groundwater target identification by Central Ground Water Board and; landuse suitability map preparation by Regional Remote Sensing Application Centre, Lucknow for the lower Betwa plain will become meaningful if their spatial representation reaches optimum standards. The potentiality of water resources in the basin exists in seasonal streams and small water bodies because the water of the perennial river Yamuna cannot be diverted to south due to general relief of the region [5]. Therefore, the study of hydrological data network becomes important in this region dominated by seasonal tributaries and uncertainty of rainfall.

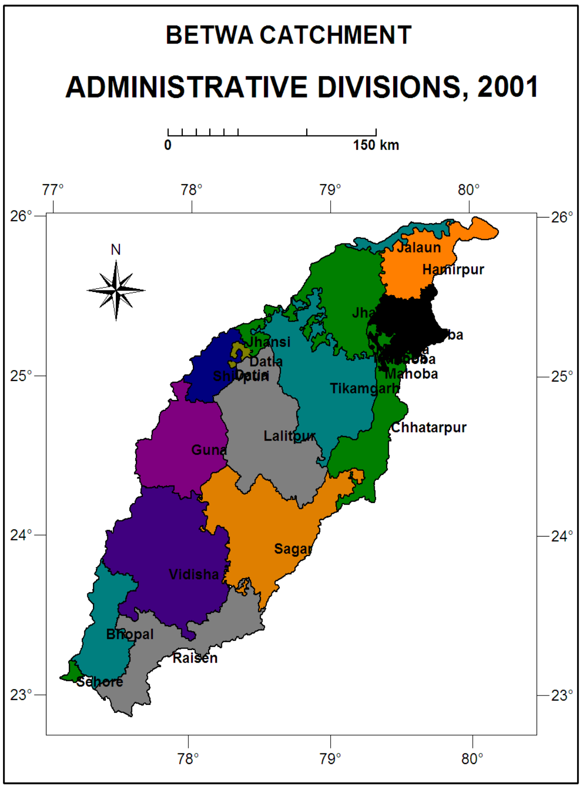

Fig. 1 Study Area

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III. DATA SOURCE AND METHODOLOGY

The analysis is based on data collected from secondary sources. Long- term annual data for hydrological stations is obtained mainly from Indian Meteorological Department (IMD). Besides annual data, monthly data from these and other state-level organisations is also collected for a period of, at least, 30 years. Base maps are drawn using 11 toposheets of Survey of India at 1:250,000 scale and 4 plates of drainage and water resources series of National Atlas Thematic Mapping Organisation (NATMO) at 1:1,000,000 scale. Further, primary data regarding the nature and functioning of data stations, maintenance, communication and publication of data, and the economic or other managerial problems, is also gathered at some of the selected sites. In order to get an unbiased decision from various choices, an analysis based on neural network was done in the present study for rain gauge stations as explained below.

A. Artificial Neural Network (ANN)

The power of neural computation comes from the massive interconnection among the principal elements (PEs), which share the load of the overall processing task, and from the adaptive nature of the parameters (weights) that interconnect the PEs [6]. Normally, a neural network will have several layers of PEs. The present study covers the most basic feed forward architecture and the multilayer perceptron (MLP). First, input rows and columns are tagged as training, validation and test data in NeuroSolution version for MS-Excel. The diagram below (Fig. 2) illustrates a simple MLP. The circles are the PEs arranged in layers. The left column is the input layer, the middle column is the hidden layer, and the right column is the output layer. The lines represent weighted connections (*i.e.*, a scaling factor) between PEs. By adapting its weights, the neural network works towards an optimal solution based on a measurement of its performance. For supervised learning, the performance is explicitly measured in terms of a desired signal and an error criterion.

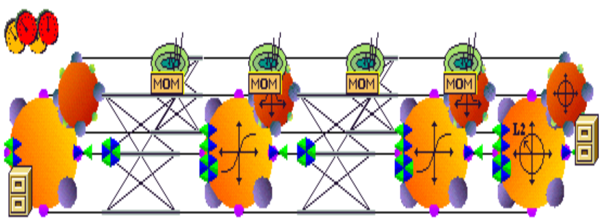

Fig. 2: A Simple Multilayer Perceptron [3]

B. Train Genetic

To perform genetic training, first an initial population of networks is randomly created with each having a different set of parameters. Each of these networks is then trained and evaluated (to determine its fitness) based on the minimum error it achieved. The characteristics of the good networks are then combined and mutated to create a new population of networks. Again, the networks in this population are evaluated and the characteristics of the best networks are passed along to the next generation of networks. This process is repeated until the maximum generations or maximum evolution time is reached or the user stops the evolution. After training, a report is automatically generated summarizing the results.

C. Sensitivity about Mean

This testing process provides a measure of the relative importance among the inputs of the neural model and illustrates how the model output varies in response to variation of an input. The first input is varied between its mean +/- a user-defined number of standard deviations while all other inputs are fixed at their respective means. The network output is computed for a user-defined number of steps above and below the mean. This process is repeated for each input. A report is generated which summarizes the variation of each output with respect to the variation in each input.

IV. RESULTS AND DISCUSSION

The sensitivity of proposed and existing stations to mean values was analysed in a relative unbiased manner using multi-layer perceptron method based on artificial neural network analysed in Neuro-Solutions Excel-based software. For training of network two input layers - weekly rain gauge data and hydrograph stations data for selected months were used separately and weights for two hidden layers in each set were determined by software in three different runs. Best network results were obtained in 3rd run having minimum error (Table I and II).

A genetic feed forward algorithm was used to get the result form the same data wherein again 7 stations were identified as most sensitive to mean values of the catchment (Table III). Hence, these stations are located at very critical locations and any change in their locational settings can change the regional estimates of mean (Fig. 3). New centres in this zone are essential to neutralise the effect of variation. On the other hand, very closely spaced least sensitive stations like Pachwara, Magarwara, and Belathal can be reduced in number because they won't change regional estimates significantly. The choice of new stations can also be determined in the similar manner by interpolating values at other grid points.

Table 1: Multilayer Perceptron (MLP) Run Results

All Runs	Training Minimum	Training Standard Deviation	Cross Validation Minimum	Cross Validation Standard Deviation
Average of minmum MSEs	0.00034	0.00023	0.00117	0.00145
Average of final MSEs	0.00034	0.00023	0.00117	0.00145

Best Networks	Training	Cross Validation
Run #	3.00000	2.00000
Epoch #	1000.00000	1000.00000
Minimum MSE	0.00018	0.00033
Final MSE	0.00018	0.00033

Source: Computed in Neuro-Solutions

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Table II: Hidden Layer Runs

Hidden 1 PEs	Training	+ 1 Standard Deviation	- 1 Standard Deviation	Cross-Validation	+ 1 Standard Deviation	- 1 Standard Deviation
2	0.000382	0.000477	0.000287	0.008833	0.009633	0.008033
3	0.000339	0.000403	0.000275	0.010763	0.012635	0.008891
4	0.000422	0.000685	0.000159	0.007219	0.010715	0.003722
5	0.000419	0.000582	0.000255	0.009100	0.009370	0.008829

Source: Computed in Neuro-Solutions

Table III: Genetic Algorithm Test Report

Best fitness	Average fitness
0.00345761	0.00914588
0.00104459	0.00755379
0.00104459	0.00651708
0.00104459	0.00560095
0.00104459	0.00509204
0.00104459	0.00462147
0.00104459	0.00394113
Minimum best fitness	Minimum average fitness
0.00104459	0.00394113

Optimization summary	Best fitness	Average fitness
Generation #	2	7
Minimum MSE	0.001044589	0.003941131
Final MSE	0.001044589	0.003941131

Source: Computed in Neuro-Solutions

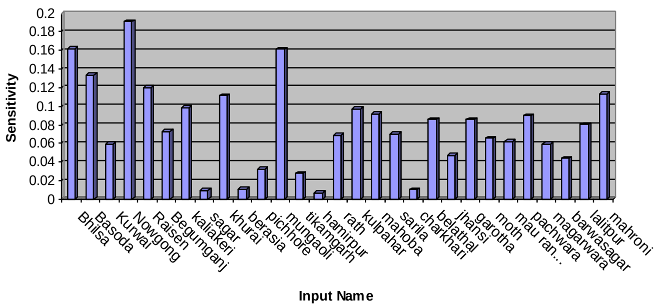

Fig. 3: Sensitivity Analysis

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