ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 13, Issue, 07, pp. 63328-63334, July, 2023
https://doi.org/10.37118/ijdr.26991.07.2023

RESEARCH ARTICLE OPEN ACCESS

BUILDING AUTOMATIC ARTIFICIAL NEURAL NETWORK PROGRAM TO FORECAST RESERVOIR INFLOWS IN A RIVER BASIN – CASE STUDIES IN VIET NAM

***Le Van Duc**

Faculty of Civil Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam

ARTICLE INFO

Article History:
Received 20th April, 2023
Received in revised form
14th May, 2023
Accepted 06th June, 2023
Published online 30th July, 2023

KeyWords:

AI, ANN program, Automatically search for solutions, Forecast flows, River basin.

Corresponding author: Le Van Duc,

ABSTRACT

The comments of scientists and managers of water resources management have recently emphasized that water is very precious to serve and develop socio-economic. Therefore, the use of Artificial Intelligence (AI) technology, especially Artificial Neural Network (ANN) to manage water resources and forecast the hydrological variables for river basins is essential. Hereinafter, the ANN-river basin program system has been introduced to allow data management, computation to predict the inflow into reservoirs, which introduces convenient mechanisms for creating input data, automatic solution finding for ANN program. The program has been applied to forecast the inflows into Tri An reservoir in different time steps and daily inflow into Thac Mo reservoir. The results show that this ANN program system is rather convenient, and consumes rather less time to obtain the solutions with high accuracy. For larger Dong Nai river basin, a diagram showing the relationship between the accuracy and time step to forecast the inflow into Tri An reservoir was obtained. It showed that, to ensure the forecasting result about 80% of accuracy (EI), the forecast time should not exceed 10 days. While, for smaller Be river basin, the accuracy to forecast daily inflow into Thac Mo reservoir was very high, 99.93%. However, for longer time steps (7-days, 10-days), the result for forecasting was almost unattainable.

Citation: ***Le Van Duc. 2023.*** *"*Building automatic artificial neural network program to forecast reservoir inflows in a river basin – Case studies in Viet Nam". *International Journal of Development Research*, 13, (07), 63328-63334.

INTRODUCTION

Le Xuan Dinh [1], in the article: "Creating breakthroughs so that science, technology and innovation become the main driving force for rapid and sustainable economic growth and national development", He gave the current status of contributions of Science and Technology of Viet Nam (ScTech-VN) for society, analyzed its limitations, and thereby, outlined the development strategies of ScTech-VN in the industrial era 4.0. The article emphasized: "…investing resources to organize the implementation of strategies on Artificial Intelligence…", including the field of Water Resources Management (WRM). Website "Vietnam Clean Energy" [2] has an article emphasizing: "The field of Science and Technology of Water Resources (ScTech-WR) plays an important role in the case of socio-economic development, ... environmental protection, serving the country's sustainable development and ensuring national water security. Therefore, the field of ScTech-WR should be prioritized for investment and development, one step ahead to serve as a basis for policy making for socio-economic development... To realize these goals, the solution for scientific and technological development of water resources in the 2021-2025 period will focus on promoting the application of information technology in the management, collection, processing and provision of information and data on water resources to serve for the socio-economic development needs of the community". Meanwhile internationally, Daniel Peter Loucks - Eelco Van Beek [3] showed that "Water resources are special… Life on this planet depends on water. Most of our economic activities consume water. All the food we grow, process and eat requires water…The importance of water to our well-being is beyond question. Our dependence on water will last forever.". Through this valuable statement, it shows that the development strategy of ScTech-VN, especially emphasizing the development of 4.0 technology in the field of WRM to benecessarily focused for development to optimize the use of this extremely special and rare water resource. Alabi Micheal Omotayo and Arnesh Telukdarie [4] in the article "Technology 4.0: Innovative Solutions for the Water Industry" pointed out that "… Water is one of the most valuable natural resources used for everyday living... One of the biggest challenges facing the water industry is the inability to turn the available data into insightful information that permits effective decision making.". Therefore, to process this huge data block, to find out their meaning, to make the right and informed decisions, we must rely on Artificial Intelligence solutions. One of the areas, where AI technology is applied, is Artificial Neural Networks. It is used in the field of hydrometeorology, to forecast rainfall, floods, water levels, water quality, surface water and groundwater flows, etc. These are areas where measured data is abundant. However, to use and extract scientific meaning from it to support human decisions is still quite limited. Rakesh Tanty and Tanweer Sultanah Desmukh[5] has comprehensively reviewed the applications of ANN used in hydrological related fields, when the traditional methods encountered obstacles because the problem processing became cumbersome and quite complicated from the point of view of computational analysis. The operation of AI can be clearly illustrated through application in precipitation-flow model, flow model, water quality model and application in groundwater. However, a good physical understanding of the hydrological process being modeled is required, which can help in selecting input vectors and designing ANN networks more efficiently. Hikmet Kerem Cigizoglu [6] compared different neural network techniques in predicting short-term continuous and intermittent daily stream flow forecasting and daily suspended sediment forecasting. Three different ANN techniques, namely, feed forward back propagation (FFBP), generalized regression neural networks (GRNN) and radial basis function-based neural networks (RBF) are applied to the hydrologic data. In general, the forecasting performance of ANN techniques is found to be superior to the other conventional statistical and stochastic methods in terms of the selected performance criteria. Therefore, in this article, the author analyzes the physical nature of the application of ANN technology in the field of hydrometeorology, analyzes algorithms and programming technology to aim at creating a program to apply ANN technology for the river basins, in such a way that, in general, it is convenient in data import and export, results evaluation, program execution, especially in the training phase of the network effectively.

The overview of the ANN-river basin program

General scheme of the system: ANN-river basin program system (See Figure 1): Used to compute, simulate and forecast the flow into the reservoir or at the river cross-section in the basin, based on the hydrometeorological data of the measuring stations in the river basin area.

GIS program: Used to store spatial and temporal information, hydrometeorological stations and display a digital map of the basin (see Figure 2). The Access-Database Management program to contain all geotechnical data of the measuring stations in the basin, in HOUR time step, updated to DAY, WEEK, 10-DAYS, 15-DAYS, MONTH & YEAR periods thanking to the support of the VBA EXCEL program; to create input files for ANN Program (ANN-Prog).

ANN-Program: Computing in 3 stages: training the network, testing the network and applying for prediction. In addition, in order to facilitate and quickly train the network and find the appropriate structure, it is programmed with an Automatic Solution Finding tool (AUTO-TRAIN). In addition to presenting a comparison chart between calculated & measured data in the program, EXCEL software is also embedded to perform this function more flexibly.

Database: The ACCESS database in the MS Office software is used and named as db.mdb, see Figure 3. The database contains tables, together with manipulation forms, to perform the functions of managing hydrometeorological data, GIS data; and to create the input files for ANN model.

Programs integrated in the database

The ACCESS database has data manipulation programs including:

- Managing hour-, day-, week, 10-day-,15-day-,month and year-data;
- Create input files for the ANN program
- Starting the ANN-Prog;
- Presenting the report table of computation results from ANN-Prog.

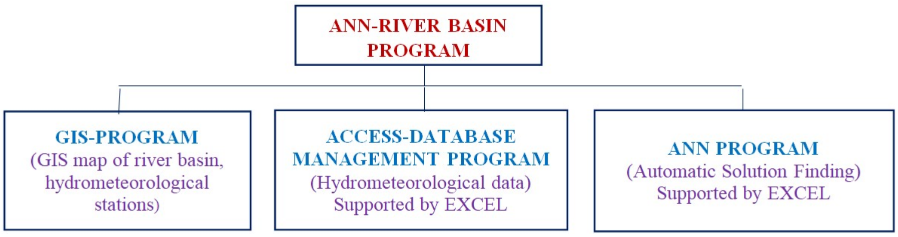

Figure 1. General scheme of ANN-River Basin Program

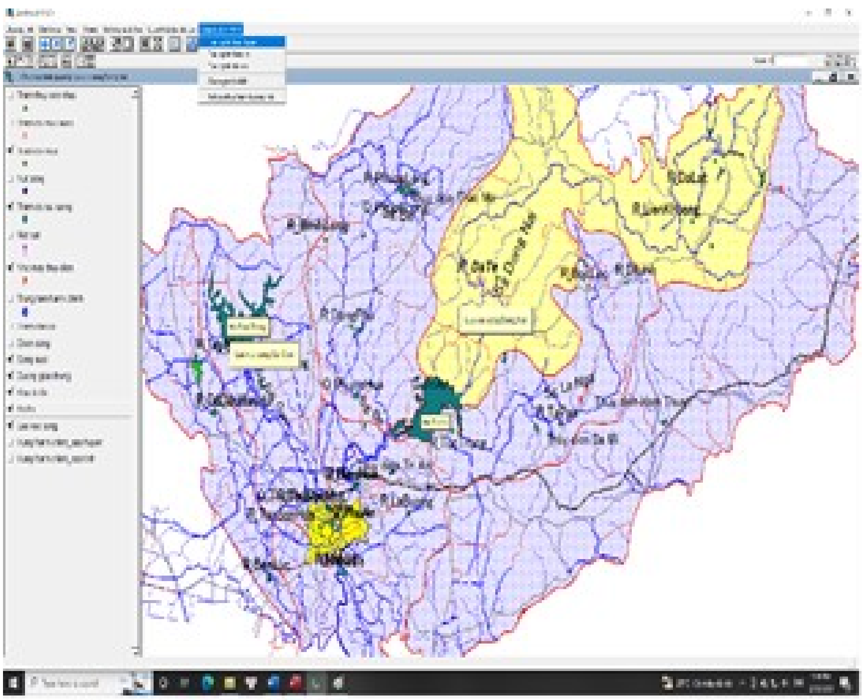

Figure 2.The overall interface of the ANN-Dong Nai River Basin program

Program creating input files for the ANN program: Figure 4 shows the interface of the Input File Generator Program during the training phase. It allows to perform functions related to: Data selection, data checking, data structure creation for ANN programs.

ANN-Prog

ANN model for flow forecasting in the river basin: ANN with the architecture of the multi-layer perceptron network (MLP) is used here. It includes one input layer with several nodes being the independent variables for hydrometeorological data; output layer, here with one node being the forecasting dependent variable; and one or several hidden layers(more details in mathematical description, click on: ANN-MLP Architecture). This relation between ANN model and flow forecast diagram in river basin is shown in Figure 5.

Back Propagation Neural Network Algorithm (BPNN): There are several methods that can be used for training the structure. In this study the BPNN is used. It mainly includes two phases: (1) forward phase: the available (or random for the first time) weightings are used to proceed the computation from the input layer to output layer to find out the error; (2) backward phase: the computation proceeds from the output layer back to the input layer to adjust the weightings based on the obtained error. This forward-backward computation process is repeated many times until obtaining the error at the target (output) node less than an allowable value. This algorithm is shown in the Figure 6 (more details in mathematical description, click on Appendix 1).

The arrangement of the ANN-river basin system: All components of the system are stored in the directory named.

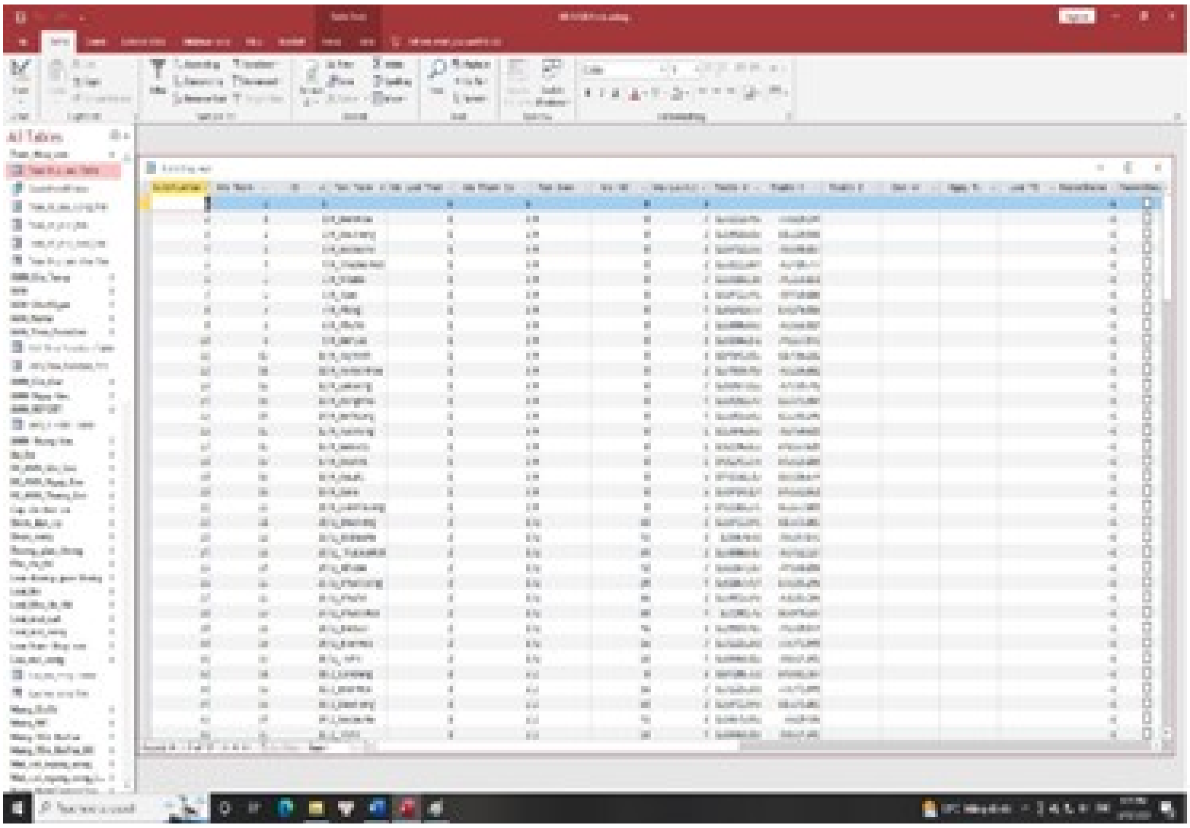

Figure 3. Hydro-Station table stores hydrological data of the basin

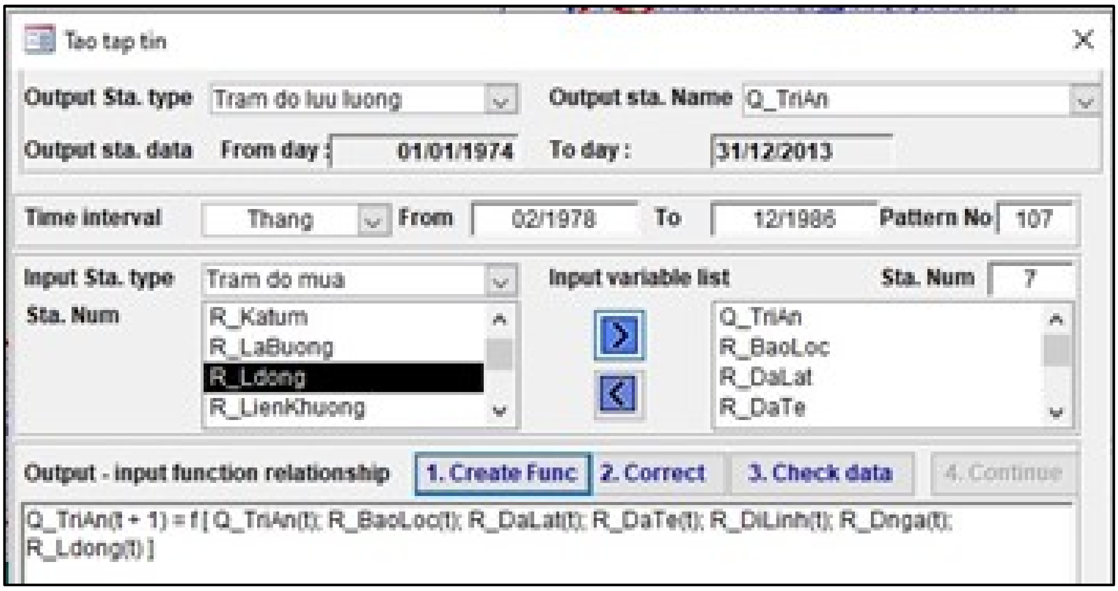

Figure 4. Create a training data file for the ANN program

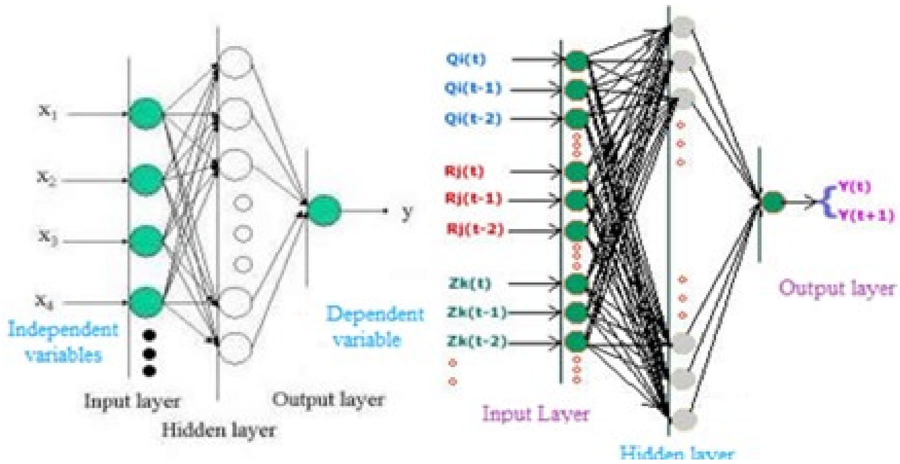

Figure 5. The structure of 3-layer ANN for Forecasting the river flow in a reviver basin

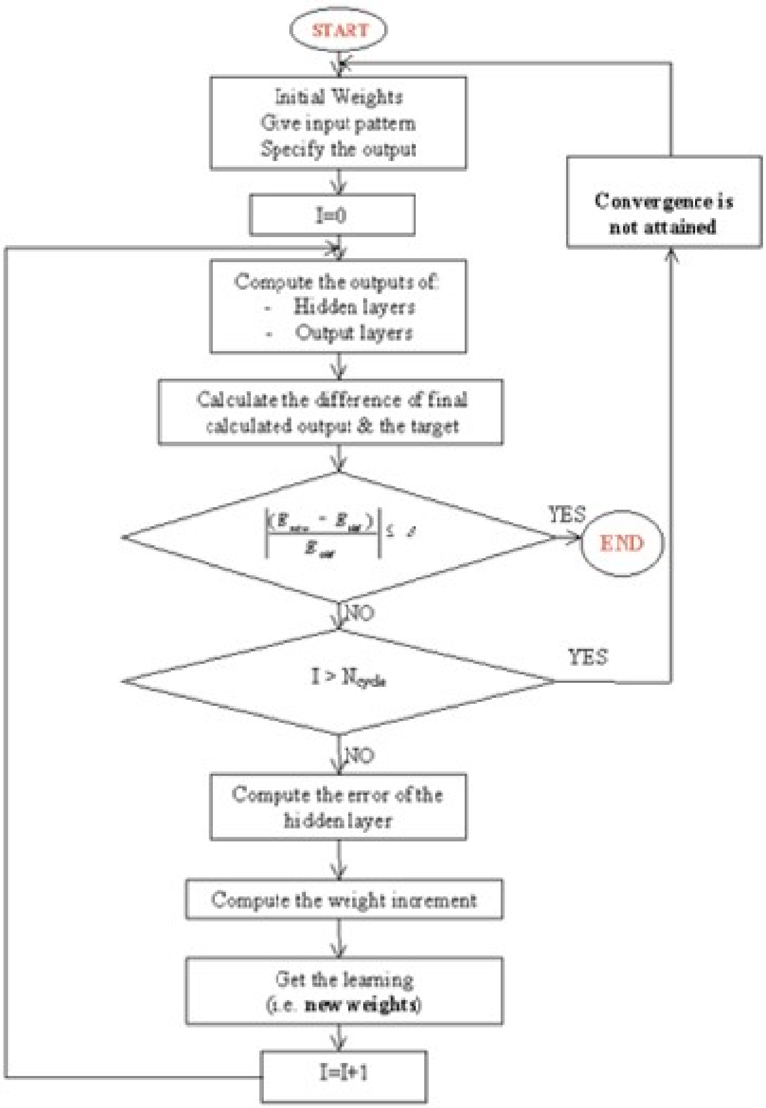

Figure 6.The flow chart of the BPNN algorithm

Dong Nai_River Basin_GIS including:

- The Arcview-GIS named dnrbgis.apr is stored in the directory; *DongNai_RiverBasin_GIS*.
- The Microsoft Access Database-VBA with name: db.mdb is stored in *DongNai_RiverBasin_GIS/Access;*
- ANN-Prog is written by VBA language and stored in the directory *DongNai_RiverBasin_GIS/ANN*.
- The input and output data files are stored in the directory: *DongNai_RiverBasin_GIS/ANN_Data*.

All these components are installed in Windows 10(or later) on a desktop computer along with the Microsoft Office 2019 (or later), Visual Basic 6.0, and Arcview-3.2a with some amendments during the installation process to make the system workable together.

The interface of ANN-Prog: The ANN-Prog is shown in Figure 7. It consists of three main computational functions: Training the network, Testing and Forecasting the network. It allows users to select network parameters, accuracy performance, reused weights from previous run,

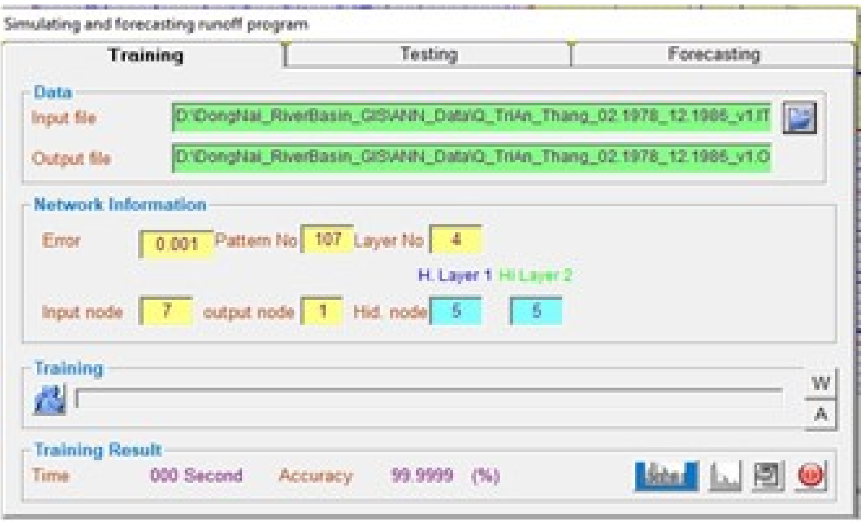

Figure 7. ANN program

Table 1. Time step and period used for training and testing phases to forecast the Tri An reservoir inflow

Order	Time step	Time period for training phase	Time period for testing phase
1	1-day	From 05/01/1978 to 30/11/1987	From 01/02/1989 to 30/11/1991
2	7-day	From 05/01/1978 to 22/10/1987	From 05/01/1989 to 24/10/1991
3	10-day	From 04/01/1978 to 03/12/1987	From 04/01/1989 to 10/11/1991
4	15-day	From 03/01/1978 to 26/01/1988	From 03/01/1989 to 19/11/1991
5	1-month	From 02/1978 to 11/1987	From 02/1989 to 11/1991

automatic solution finding, and output results via a comparison graph between computational and measuring data. The interface of automatic solution finding function is shown in Figure 8.

Criteria

Statistical parameters to evaluate simulating or forecasting results:

The Efficiency Index (EI) is suggested by Nash and Sutcliffe[7]:

$$EI = \frac{SST - SSE}{SST} \quad \text{where} \quad SST = \sum_{i=1}^{T}(Q_i - Q_{av})^2 \quad \text{and} \quad SSE = \sum_{i=1}^{T}(Q_i - F_i)^2$$

Where Q_i is the measured discharge at time i ,Q_{av} is the average measured discharge over time T; F_i is the simulating or forecasting result at time i.

Some results of application of the ann-river basin program in Vietnam

Finding a reasonable time step to forecast the inflow into Tri An Reservoir [8]: Dong Nai river is the second biggest river in the South of Viet Nam, after Mekong river. It locates in the Middle of Viet Namhaving basin area of 38,600 km² (See the upper yellow area in Figure 2). While Tri An reservoir, a hydropower reservoir at downstream of Dong Nairiver, receives water from this river basin. To forecast the inflow into this reservoir in the rainy season is very important for multiple-purpose optimal operation among power generation, safety of construction, and avoiding flooding at downstream. Therefore, hereinafter, the ANN-river basin program was applied for training to predict the inflow into Tri An reservoir in Dong Nai river basin. The criteria for comparison between computed and recorded data is Efficiency Index (EI) as presented in formula (1). The source of historical hydrometeorological data were taken from document [9]. The time periods for application in two training and testing phases are: 1-day, 7-day, 10-day, 15-day and 1-month are presented in Table 1. The purpose of this ANN-river basin program system was to find the longest time step that was reasonable to forecast the inflow into Tri An reservoir. The results show that with available rainfallstations, available data, and with topographic and geological characteristics of Dong Nai river basin, the inflow forecasting function into Tri An reservoir with the following form obtained good results:

QTriAn(t+1) = f[QTriAn(t), QTriAn(t-k), R_Baoloc(t), R_Dalat(t), R_DaTe(t), R_DiLinh(t), R_DNga(t), R_LDong(t)]………………(5)

Where, k∈ [1..5].

If the 1-dayforecasted inflow into Tri An reservoir was computed, the accuracy (EI) achieved 97.29% in the network training phase and 87.55% in the network testing phase. If 7-day forecasted inflow was computed, then the accuracy achieved less than 90%. If the 10-day forecasted inflow was computed, then the accuracy did not exceed 77%. If the inflow forecast was applied for 15 days, then the accuracy was about 70%. The results of comparing the accuracy (EI) in two phases of training and testing the network were shown in Figure 9. *Conclusion*: the computation shows that to forecast the inflow into Tri An reservoir, when the time step was short, the accuracy (EI)was high, and vice versa. For Tri An reservoir, Dong Nai river basin, with available rainfall stations, to ensure that the forecast was about 80% of accuracy (EI), the forecast time should not exceed 10 days.

Using ANN model to forecast daily inflow into Thac Mo reservoir [10]: Thac Mo reservoir is located in the Song Be basin. The Be river has two large tributaries, Dak Lap and Dak Glum, with the direction of flow to the southwest almost parallel to each other. The main river (according to the Dak Glum branch) has a length of 331km, originates from the Xnaro plateau (over 950m high) and flows into the Dong Nai river in Hieu Liem. Be river basin is located in coordinates: 11° 04' 43”-12°20' 51” North latitude, l06°34'54”- l07°31’01” East longitude (see Figure 10). The area of Be river basin is 7,484.05 km^2 [11]. To forecast the flow into the reservoir follows the below information: the training phase started from May 1, 1995 to November 30, 2010. Total days for training phase are 5692. The testing phase started from May 1, 2010 to November 30, 2011. Total days for testing phase are 578. The source of historical data series is taken from the document [10]. To compare the performance of the ANN model, four options has been proposed, based on the discharge, rainfall in the basin, time phase difference. The ANN functions areas follows:

Opt 1: Q_Thmo(t + 1) = f [R_Bdang(t); R_BDop(t); R_BNho(t); R_Dpan(t); R_LocNinh(t); R_Plong(t)];

Opt 2: Q_Thmo(t + 1) = f [Q_Thmo(t); R_Bdang(t); R_BDop(t); R_BNho(t); R_Dpan(t); R_LocNinh(t); R_Plong(t)];

Opt 3: Q_Thmo(t + 1) = f [Q_Thmo(t); Q_Thmo(t - 1); R_Bdang(t); R_BDop(t); R_BNho(t); R_Dpan(t); R_LocNinh(t); R_Plong(t)];
Opt 4: Q_Thmo(t + 1) = f [Q_Thmo(t); Q_Thmo(t - 1); Q_Thmo(t - 2); R_Bdang(t); R_BDop(t); R_BNho(t); R_Dpan(t); R_LocNinh(t); R_Plong(t)];

Where, Q_Thmo: The discharge into Thac Mo reservoir; R_Bdang: Rainfall at Bu Dang station; R_BDop: Rainfall at Bu Dop station; R_BNho: rainfall at Bu Nho station; R_Dpan: Rainfall at Dong Pan station; R_LocNinh: Rainfall at Loc Ninh station; R_Plong: rainfall at Phuoc Long station. All these rainfall stations are belonged to the Be river basin.

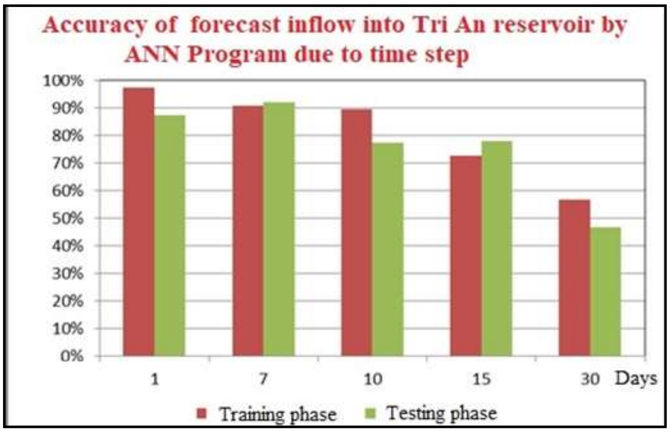

Figure 9. Accuracy (EI) of Flow forecast into Tri an reservoir by time step using ANN program

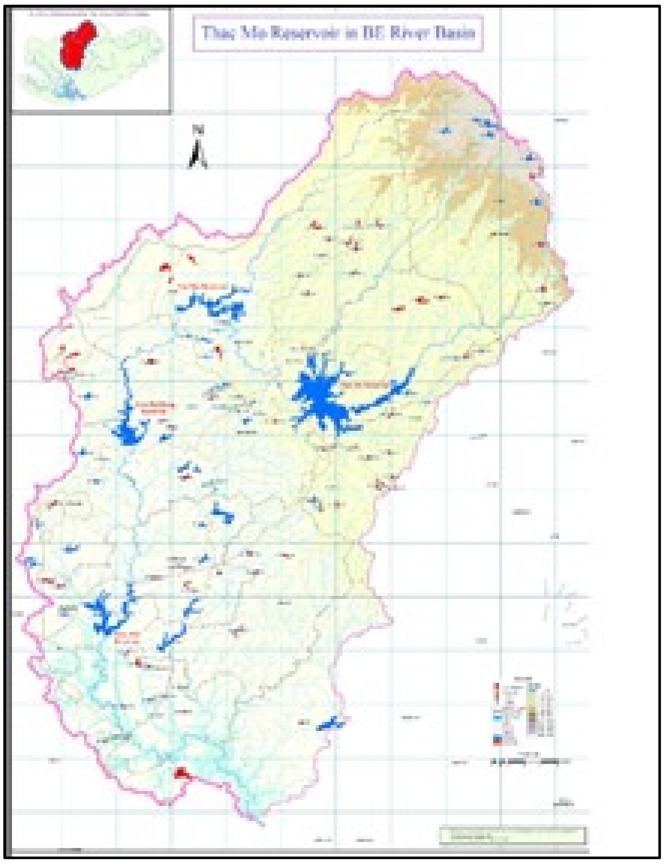

Figure 10. The Mo reservoir in Be river Basin

The structure of ANN model includes: input layers: 6 nodes for Opt 1; 7 nodes for Opt 2, 8 nodes for Opt 3 and 9 nodes for Opt 4; The hidden layer consisting of 15 nodes; and the destination layer consists of 1 node which is the forecasted daily inflow into Thac Mo reservoir in the next day (Q(t+1)) (Figure 11).

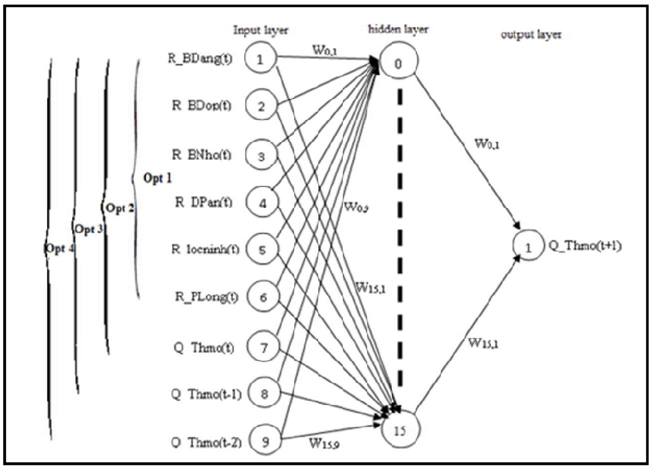

Figure 11. The Options and structure of ANN Model to Forecast the daily inflow into Thac Mo Reservoir

The results for running four options is shown in Table 2.

Table 2. Computation results of daily flow forecast into Thac Mo reservoir in the network training phase: from May 1, 1995 to November 30, 2010

Opt.	Q_{av}	EI
1	123.55	-28.76%
2	123.55	-52.35%
3	123.55	99.93%
4	123.55	-60.81%

From Table 2, we can see that the accuracy of Opt 3 is very high, with the EI of 99.93%. So, the opt 3 is selected for running testing phase. The result of testing phase is shown in Table 3, in which the accuracy (EI) obtained 84.31%.

Table 3. Computation results of daily flow forecast into Thac Mo reservoir in the testing phase ofOpt3: from May 1, 2010 to November 30, 2011

Opt.	Q_{av}	EI
3	103.34	84.31%

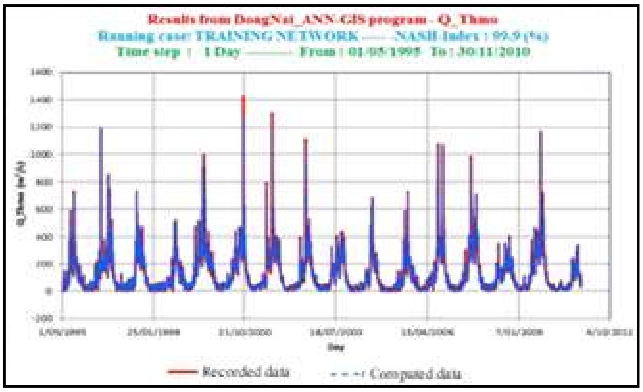

Figure 12. Forecast of daily flow into Thac Mo reservoir during the training phase of Opt.3

In conclusion, the accuracy of daily forecast into Thac Mo reservoir in the training phase is very high, with EI of 99.93% (See Figure 12). Meanwhile, the accuracy in the testing phase is rather high, 84.31% (See Figure 13). Here, the computations are not presented for longer periods because the results have been shown that the accuracy of training phases are very low. The reasons are the size of Be river basin is small in comparison with Dong Nai river basin. Therefore, the time for concentration of water from rainfall within the Be river basin to the Thac Mo reservoir is just within one day.

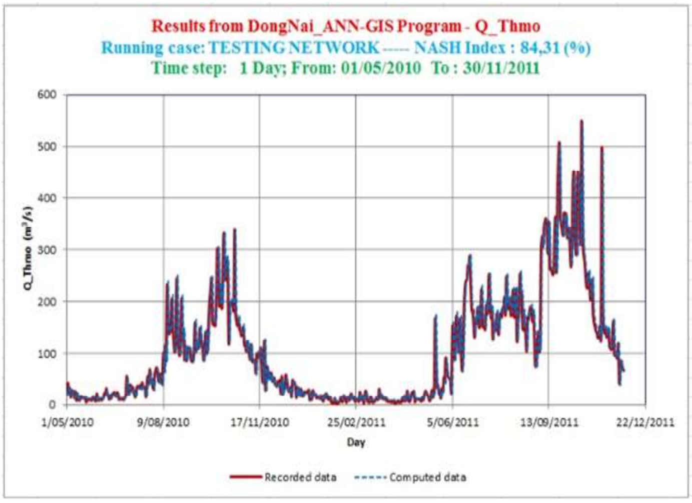

Figure 13. Forecast of daily flow into Thac Mo reservoir during the testing phase of Opt.3

CONCLUSION

The ANN-river basin program system with BPNN technique has been created and applied to river basins. It includes three main blocks: (1) ANN program; (2) The Input File Generator program helping to conveniently create input files for the ANN program; (3) The GIS program manages and displays hydrometeorological stations, and the map of river basin. Then, it has been applied to forecast the inflows into reservoirs, including the inflow into Tri An reservoir, Dong Nai river basin; the inflow into Thac Mo reservoir, Be river basin. The pretty good results and high accuracy has been obtained. As, we know, there are numerous river basins in Viet Nam. Frequently, in the rainy seasons, the flooding usually occurs, so if the forecast of flow is not timely and accurate, then the natural disaster by flooding may cause damage to the works, human beings and even economic life of communities in the affected areas. Therefore, if the application of this ANN-river basin program system is considered to these river basins, some benefits for the communities in the vicinity of river basins may obtain.

ACKNOWLEDGEMENTS

The author sincerely thanks Vietnam National University HCMC and Ho Chi Minh City University of Technology for providing funding for the project, code C2021-20-44, enabling this article to be carried out.

REFERENCES

Alabi Micheal Omotayo[1] and Arnesh Telukdarie[2] (2019) : *Industry 4.0: innovative solutions for the water industry,* Conference: Proceedings of the American Society for Engineering Management 2019 International Annual Conference E. Schott, E-H. Ng, H. Keathley, and C. Krejci eds At: USA. ResearchGate. [1]Ryerson University; (2) University of Johannesburg. https://www.researchgate.net/publication/339055922_INDUSTRY_40_INNOVATIVE_SOLUTIONS_FOR_THE_WATER_INDUSTRY.

Daniel Peter Loucks - EelcoVan Beek(2016), *Water Resource Systems Planning and Management – An Introduction to Method, Models, and Application*. ISBN 978-3-319-44234-1 (ebook); jointly published with Deltares and UNESCO-IHE; Springer.

Hikmet Kerem Cigizoglu (2008), *Artificial neural networks in water resources.* Cigizoglu, H.K. Hydraulics Division, Civil Engineering Faculty, Istanbul Technical University, Maslak, 34469, Istanbul, Turkey, e-mail: cigiz@itu.edu.tr. H. Gonca Coskun et al. (eds.), Integration of Information for Environmental Security, 115–148. © 2008 Springer.

James Eamonn Nash and John Vernon Sutcliffe (1970), River Flow Forecasting through Conceptual Models. Journal of Hydrology, Vol. 10, pp. 282-290.

Le Van Duc (2017a), *Forecasting Thac Mo daily inflow using the Artificial Neural Network (ANN) model and analysis of the effect of lag-time component of discharge in the structure of ANN model*.

Le Van Duc (2017b), *Research for building a decision support system for optimal and sustainable operation of a system of linking reservoirs to assure the safety of hydraulic works, to serve for hydropower production, water supply, flooding control and salt intrusion prevention at the downstream of Dong Nai and Sai Gon rivers*. Scientific Research Project, Department of Science and Technology of Ho Chi Minh City; Ho Chi Minh, March 2017.

Le Van Duc (2019), *Research on Suitable Time Step to Forecast Tri An Reservoir Inflow in Dong Nai River Basin Using Artificial Neural Network Model*, IRED, 9th International Conference on Advances in Civil, Structural and Mechanical Engineering, ACSM 19, 7-13, 2019; Journals Proceeding, International Journal of Civil & Structural Engineering, Electronic ISSN: 2372-2971, Vol. 6: Issue 2; Page(s): 103-109.

Le Xuan Dinh (2022), *Creating breakthroughs so that science, technology and innovation become the main driving force for rapid and sustainable economic growth and national development*. Article published in Communist magazine. of Dr. Le Xuan Dinh, Deputy Minister of Science and Technology (January 18, 2022), quotedon 10/2/2023.

Proceeding, National Aero Hydro Mechanics Congress, 27-29 July 2017, Can Tho, Vietnam National University – Ho Chi Minh City Publishing House, ISBN 978-604-73-6070-3.

Rakesh Tanty and Tanweer Sultanah Desmukh (2015). *Application of Artificial Neural Network in Hydrology- A Review.* International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181. Vol. 4 Issue 06, June-2015.

Tran Tuan Tu and Ha Quang Khai (2007), "Extraction of morphometric parameters of the Song Be river basin from the Digital Elevation Model", Vietnamese Geology Magazine, Series A, No. 300, 5-6/2007, pp. 64-72.

Website Vietnam Clean Energy, *Promoting scientific and technological research in the field of water resources,* https://nangluongsachvietnam.vn/d6/vi-VN/news/Day-manh-nghien-cuu-khoa-hoc-va-cong-nghe-trong-linh-vuc-tai-nguyen-nuoc-0-1951-10215 , quotedon12/2/2023.

****