# Seasonal Reservoir Release Prediction Using Anfis & Different Type of Wavelet Based Anfis

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**Abstract :The objective of this study is to water release inMaithon and Panchet reservoir by using application of ANFIS techniques for prediction of released water from reservoir at multi-time steps. Now a day everybody wants to be accurate at any particular analysis. This study presents the applications ofWAVELET-daubechies scaling and ANFIS techniques. This study will give high rate of success of accuracy in short time. The study area were choose two multi-purpose reservoir Maithon andPanchet reservoir located in Jharkhand,India . The developed models are made considering the chosen area analysis with ANFIS and WAVELET based hybrid models are compared. The comparison of models with each other is done using performance statics namely, root mean square error (RMSE), correlation coefficient (CC),mean absolute error (MAE) and NashSutcliffe Efficiency (NSE).The results obtained after testing shows that single models using WAVELET -daubechies 3 (db3) is much more accurate than single ANFIS multi –time stepsreservoir,WAVELET db3, db5 basedwavelet and WAVELET db9. Finally, we will show that integrated WAVELET -db3 is more accurate and consistent among all models.**

**Keywords: Wavelet Transform, ANFIS, daubechies, reservoir.**

## I. INTRODUCTION

In recent years, the uneven distribution of water resources and increasingly imbalanced water demand have promoted greater need for transferring water from one basin with sufficient water to another basin facing water shortages. Inter-basin water transfer project, man-made conveyance schemes, is an efficient solutions to relieve the water-supply pressure and ensure balanced economic development among different regions. Reservoir release is important in activities such as flood control and management, design of hydraulic structures in a watershed, and likewise. The reservoir release is a complex, dynamic, and non-linear process, which is affected by many and often interrelated, physical factors. The influence of these factors and many if their combinations in generating reservoir release is an extremely complex physical process, and is not clearly understood. Moreover, many of these deterministic reservoir release models need a large amount of data for calibration and validation purpose, and are computationally expensive. There are different methods including classical regression methods, such as rime series, in one hand and novel soft computing approaches, such as neuro-fuzzy inference system (ANFIS) and different types of daubechies wavelet based ANFIS on the other hand. The progress in modeling of reservoir operative system, advanced computational tools like ANN, ANFIS, SVM, etc, are providing more advantageous in providing relatively accurate & better results in less time.

Nowadays, using only single reservoir model is inappropriate while WAVELET-daubechies 3 transform hybridized model can be used which are more accurate and give useful information on various resolution and is more significant. The purpose of this study is to give more accurate and appropriate information developing real time model using ANFIS and WAVELET hybrid model db3 to the operator in form of multi-time ahead release prediction for efficient reservoir operation.

In, the present real time study, multipurpose reservoir i.e.; Maithon and Panchet of Jharkhand, India were chosen and models were developed to apply ANFIS and wavelet hybrid model WAVELET-db3,WAVELET-db5,and WAVELET-db9. The prediction of water release at multi time steps is done using daily inflows, daily water elevation, outflow from reservoir and their lagged value for the seasonal period. Finally, comparison among ANFIS single model and WAVELET-db3 hybrid model, WAVELET-db5and WAVELET-db9 for prediction of water release is done to get the best results amongst both ANFIS & WAVELET-db3 which will suit the model for the reservoir. But WAVELET-db3 gives more accurate result than ANFIS in minimum duration of time.

## II. STUDY AREA AND DATA COLLECTION

Two major dams of Damodarvalley has been chosen in this study i.e. Maithon dam and Panchet Dam for demonstrating the application of machine learning techniques as given in figure 1. Maithon dam is located on Barakar river in Jharkhand at a latitude of 23˚ 47’ and longitude of 86˚ 49’, while Panchet dam is located across Damodar river in Dhanbad district of Jharkand at a latitude of 23˚ 40’ and longitude of 86˚ 44’. Maithon dam is the biggest dam of Damodar Valley Corporation and the largest in Jharkhand and the reservoir came into being in 1957. Both the dams have been mainly designed for flood control, irrigation and power generation.The length and height ofMaithon dam is 4,789 m and 50 m respectively with a catchment area spread of 6,249 square km. The average annual basin precipitation is 114 cm with average annual runoff of 2,616 million cubic meter. The Panchet reservoir has a catchment area of 10,961 square km. The average annual basin precipitation of Panchet reservoir is 114 cm with an average annual run off of 4540 million cubic meter. For generation of hydropower, the Maithon dam is installed with 3 units of 20 MW each, and it is two units of 40 MW for Panchet dam. The Maithon and Panchet dams have been able to significantly reduce daily and annual discharge and also largely eliminated the extreme flows in the Damodar valley. The daily observed data of inflow, reservoir water level and release of both Maithon and Panchet reservoir for a period of 16 years have been collected from Damodar Valley Corporation, Kolkata. The study of the reservoir release prediction study is carried out only for the monsoon periods i.e. from Juneto October.

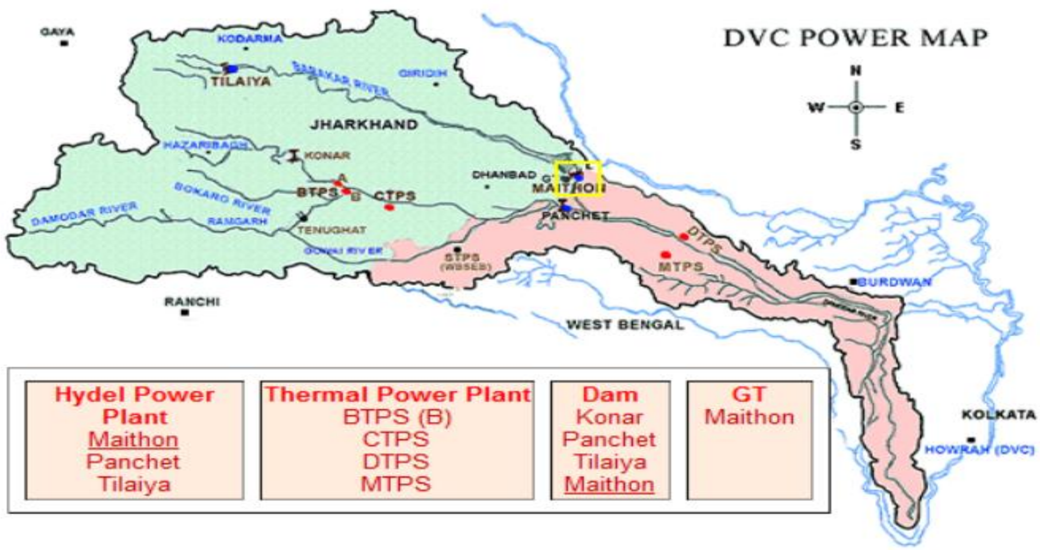



Figure1: Map of Maithon and Panchet reservoir.

## III. ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

Adaptive Neuro fuzzy inference System(ANFIS) is one of the most widely used Neuro fuzzy networks and is a powerful tool for analyzing complex non-linear processes with successful application to many hydrological problems. Takagi-Sugeno (TS) is one of the most accurate fuzzy inference models. In the TS fuzzy inference system, a fuzzy rule is constructed using a weighted linear compound of crisp inputs rather than a fuzzy set. In the first order TS fuzzy inference system, a common rule set of fuzzy IF-THEN rules is defined as follows:

Rule1: IF $x$ is $A_1$ and $y$ is $B_1$ THEN $f_1 = p_1 x + q_1 y + r_1$ (1)

Rule1: IF $x$ is $A_2$ and $y$ is $B_2$ THEN $f_2 = p_2 x + q_2 y + r_2$ (2)

where, $A_1, A_2$ and $B_1, B_2$ denote membership values of input variables $x$ and $y$ respectively; $f_1$ and $f_2$ are the output functions with $p_1, q_1, r_1$ and $p_2, q_2, r_2$ are the design parameters. In this study, triangular membership function was selected and employed to the models as input data. ANFIS consists of five layers, and the basic functions of each layer are input, fuzzification, rule inference, normalization and defuzzification. In the present study, each fuzzified inputs of ANFIS model was tuned with a hybrid method combining the back propagation gradient descent and least squares method in estimation of parameters.

## IV. WAVELET TRANSFORM AND ANFIS MODELS

The waves of wavelets have zero mean value and are of effectively short duration . Wavelet transform are used to break a signal into shifted and scaled version of original data. This process is known as multi- resolution analysis. There are mainly two types of wavelet transform such as Continuous Wavelet Transform(CWT) and Discrete Wavelet Transform(DWT). But discrete time signal has more impact in practical applications of hydrology rather than continuous time signal. So in the present study wavelet- GP was formed by discrete wavelet transform components to achive a more powerful non- linear prediction model. In WANFIS model, wavelet decomposed components are taken as input for predicting current day, one- day and two-day ahead reservoir water releases. The daily inflow, water level and outflow of reservoir were decomposed into sub-components (approximation $A_3$, details $D_1$, $D_2$, and $D_3$) with Wavelet daubechies-3 (db3) as the mother wavelet using a MATLAB code which includes Mallat's DWT algorithm.Each input combinations were created in ANFIS and wavelet-ANFIS using three numbers of triangular membership functions. In ANFIS and GP, the input time series have been decomposed in three resolution levels based on the formula, *L=int [log(N)],* where L,N are decomposition level and number of time series data respectively.Four statistical methods were selected to analyse the performance of models namely root mean square error (RMSE), correlation coefficient (CC), mean absolute error (MAE) and Nash-Sutcliffe Efficiency (NSE) and is expressed mathematically in Table 1.

Table 1

| Performance Measure | Mathematical definition |
|---|---|
| Root Mean Square Error (RMSE) | $\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Q_i-\hat{Q}_i\right)^2}$ |
| Correlation coefficient (CC) | $\frac{\sum_{i=1}^{n}\left(Q_i-\overline{Q}_i\right)\left(\hat{Q}_i-\overline{\hat{Q}}_i\right)}{\sqrt{\sum_{i=1}^{n}(Q_i-\overline{Q}_i)^2\sum_{i=1}^{n}\left(\hat{Q}_i-\overline{\hat{Q}}_i\right)^2}}$ |
| Mean Absolute Error (MAE) | $\frac{1}{n}\sum_{i=1}^{n}\left\|\hat{Q}_i-Q_i\right\|$ |
| Nash-Sutcliffe Efficiency (NSE) | $1-\frac{\sum_{i=1}^{n}(Q_i-\overline{\hat{Q}}_i)^2}{\sum_{i=1}^{n}(Q_i-\overline{Q}_i)^2}$ |

Table 2. Statistical criteria for evaluation of models

where, $Q_i$ = observed data, $\hat{Q}_i$ = predicted data, $\overline{Q_i}$ is average of observed data, $\overline{\hat{Q}}_i$ is average of predicted data, n is the number of data length.

## V. MODEL FORMULATION AND PARAMETERS

The gamma test has been done before selecting the required input data length in training and testing. The combination of 80% training and 20% testing was found as the best gamma test of results with gamma test score of 0.0930 and v ratio of 0.3729. Hence this proportion of data partitioning is used for comparing model performances. Each input time series goes through auto-corelation function and partial auto- correlation function and the lags associated with each variables has been determined. The input $I_t$, $I_{t-1}$, $I_{t-2}$, $H_t$, $H_{t-1}$, $H_{t-2}$,$Q_{t-1}$,$Q_{t-2}$,$Q_{t-3}$was used to develop nine numbers current day prediction models; ten numbers for one day ahead using $I_t$, $I_{t-1}$, $I_{t-2}$, $H_t$, $H_{t-1}$, $H_{t-2}$,$Q_t$, $Q_{t-1}$,$Q_{t-2}$,$Q_{t-3}$ and ten numbers for two day ahead prediction models using $I_t$, $I_{t-1}$, $I_{t-2}$, $H_t$, $H_{t-1}$, $H_{t-2}$,$Q_t$, $Q_{t-1}$,$Q_{t-2}$,$Q_{t-3}$. Here, I, H and Q are represented as reservoir, reservoir water level and outflow from reservoir respectively and t is represented as current day time and lags is represented by t-1, t-2 and t-3 respectively associated with all variables. For all ANFIS, wavelet based ANFIS and wavelet baed models. The total data set of inflow, water level and outflow from reservoir was scaled in the range of 0 to 1.

## VI. RESULT AND DISCUSSIONS

In table 2 and 3 the comparsion has been done on the basis of satatiscal performanes of MAITHAN and PANCHET reservoir in trainig and testing for the different models for predicting different day reservoir water releases, such as-ANFIS, WANFIS, WAVELET DAUBECHIES-3 (db3) and WAVELET DAUBECHIES-5 (db5), prediction models for current day, one-day ahead and two-day ahead reservoir water releases. From comparison of all models, it can seen that WAVELET – ANFIS and WAVELET - DAUBECHIES-3 are more precise models in predicting reservoir water release for current day and multi-step ahead forecast. Overall the statistical result of Wavelet hybird models indicate that the application of wavelet decomposed input further provides a more potential improvement over the single ANFIS and WAVELETDAUBECHIES-3 models. From this it can be concluded that the WAVELET hybird models use sub compenents such as information about non linearity, non stationary and seasonality behaviour in input time series, when as single models use only raw time series data as input values for modeling. It can be concluded that the new Wavelet- deubechies 3 and WANFIS are more robust models. Wavelet hybird models have also some disadvantages. Wavelet hybird models porformed better but gane relatively reduced performances for one-day and two-day ahead prediction in comparison to current day prediction. In comparison Wavelet- db3 gave the best consistent performance in both training and testing period for both Maithon and Panchet reservoir. The WANFIS models was devloped by using all the wavelet decomposed components for all input variable in WAVELET- db3 model , WAVELET - db5, WAVELET - db9 models,the insignificant decomposed componenets of input variables get eliminated automatically after mutation and cross over process in the final formula of WAVELET- db3 and WAVELET - db5 prediction models. By the comparison of reservoir releases using the optical WANFIS and WAVELET- DAUBECHIES -3 (db3) mother wavelet and single ANFIS and WAVELET- DB3 models for current day training and testing periods of Maithon and Panchet reservoirs by the comparison, it can be observed the estimates of the WANFIS and WAVELET- db3 and single ANFIS and WAVELET- db3 models for current day prediction are less scattered and closes to the line of perfect fit both in training and testing. Panchet reservoir fits more then Maithon reservoir. Form table 2 & 3, the WAVELET - db3 have the least root mean square value among all models both in training and testing and for all lead time forecasts. The WAVELET - db3 have highconsistent value ofNash-Sutcliffe efficiency in training and testing. In Maithon Dam, the RMSE and CC values of ANFIS and db3 Wavelet based ANFIS, testing improved noticebly of current day forecasts and one day ahead forecasts is ranging from 0.016 to 0.009 and 0.025 to 0.021. In Panchet Dam, the RMSE and CC values of ANFIS and db3 Wavelet based ANFIS, testing improved noticebly of current day forecasts and one day ahead forecasts is ranging from 0.020 to 0.013 and 0.0945 to 0.960. In comparetively, ANFIS and db3 Wavelet based ANFIS models give some results, but db3 Wavelet based ANFIS is best due to the results coming in RMSE value is nearest about 0 (zero),and CC value is nearest about 1.

Table 2- Result of Maithon

| **Lead Time** | **Criterion used** | **ANFIS** | | **db3Wavelet** | | **db5Wavelet** | | **db9Wavelet** | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Training** | **Testing** | **Training** | **Testing** | **Training** | **Testing** | **Training** | **Testing** |
| **Current Day Forecast** | **RMSE** | **0.019** | **0.016** | **0.012** | **0.009** | **0.015** | **0.011** | **0.017** | **0.027** |
| | **CC** | **0.958** | **0.918** | **0.979** | **0.968** | **0.973** | **0.950** | **0.971** | **0.862** |
| | **MAE** | **0.011** | **0.011** | **0.009** | **0.007** | **0.006** | **0.009** | **0.007** | **0.007** |
| | **NSE** | **0.925** | **0.820** | **0.957** | **0.931** | **0.953** | **0.911** | **0.943** | **0.895** |
| **One-day ahead forecast** | **RMSE** | **0.031** | **0.025** | **0.018** | **0.021** | **0.022** | **0.030** | **0.025** | **0.015** |
| | **CC** | **0.886** | **0.829** | **0.944** | **0.825** | **0.905** | **0.775** | **0.925** | **0.520** |
| | **MAE** | **0.014** | **0.011** | **0.007** | **0.008** | **0.009** | **0.015** | **0.010** | **0.013** |
| | **NSE** | **0.792** | **0.735** | **0.955** | **0.830** | **0.940** | **0.809** | **0.855** | **0.864** |
| **Two-day ahead forecast** | **RMSE** | **0.047** | **0.029** | **0.020** | **0.015** | **0.025** | **0.028** | **0.045** | **0.027** |
| | **CC** | **0.653** | **0.621** | **0.939** | **0.905** | **0.785** | **0.729** | **0.945** | **0.873** |
| | **MAE** | **0.017** | **0.015** | **0.009** | **0.007** | **0.015** | **0.013** | **0.011** | **0.011** |
| | **NSE** | **0.435** | **0.425** | **0.909** | **0.876** | **0.490** | **0.445** | **0.908** | **0.855** |

Comparison of performances of best ANFIS, Wavelet db3, Wavelet db5 & db9 models for Maithon reservoir

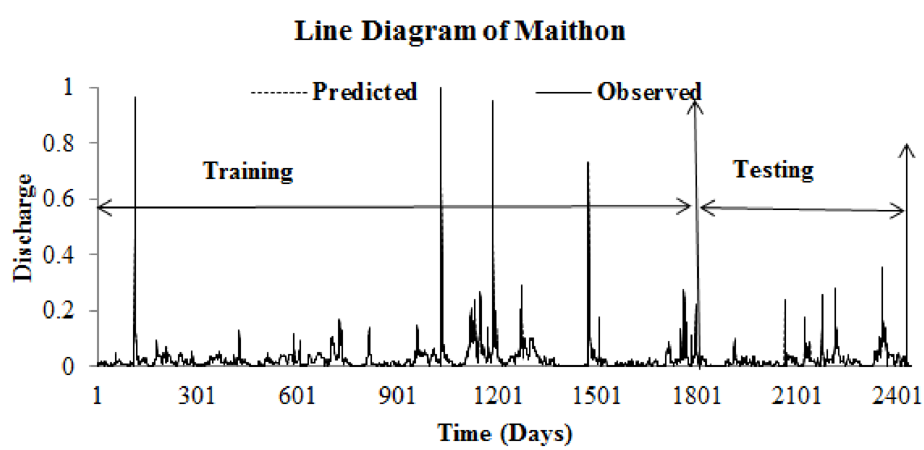
Table 3- Result of Panchet

| Lead Time | Criterion used | ANFIS | | Db3Wavelet | | Db5Wavelet | | Db9Wavelet | |
|---|---|---|---|---|---|---|---|---|---|
| | | Training | Testing | Training | Testing | Training | Testing | Training | Testing |
| Current Day Forecast | RMSE | 0.024 | 0.020 | 0.011 | 0.013 | 0.012 | 0.025 | 0.022 | 0.017 |
| | CC | 0.955 | 0.945 | 0.981 | 0.960 | 0.968 | 0.954 | 0.979 | 0.951 |
| | MAE | 0.012 | 0.011 | 0.007 | 0.008 | 0.011 | 0.010 | 0.009 | 0.012 |
| | NSE | 0.915 | 0.890 | 0.975 | 0.918 | 0.935 | 0.906 | 0.930 | 0.896 |
| One-day ahead forecast | RMSE | 0.025 | 0.021 | 0.015 | 0.013 | 0.021 | 0.017 | 0.023 | 0.020 |
| | CC | 0.940 | 0.916 | 0.991 | 0.962 | 0.978 | 0.941 | 0.935 | 0.933 |
| | MAE | 0.015 | 0.013 | 0.009 | 0.009 | 0.011 | 0.012 | 0.013 | 0.011 |
| | NSE | 0.885 | 0.815 | 0.985 | 0.917 | 0.981 | 0.945 | 0.879 | 0.838 |
| Two-day ahead forecast | RMSE | 0.045 | 0.035 | 0.025 | 0.023 | 0.020 | 0.041 | 0.043 | 0.034 |
| | CC | 0.817 | 0.775 | 0.956 | 0.917 | 0.972 | 0.804 | 0.830 | 0.777 |
| | MAE | 0.021 | 0.017 | 0.012 | 0.011 | 0.019 | 0.012 | 0.017 | 0.015 |
| | NSE | 0.665 | 0.545 | 0.930 | 0.840 | 0.945 | 0.825 | 0.689 | 0.575 |

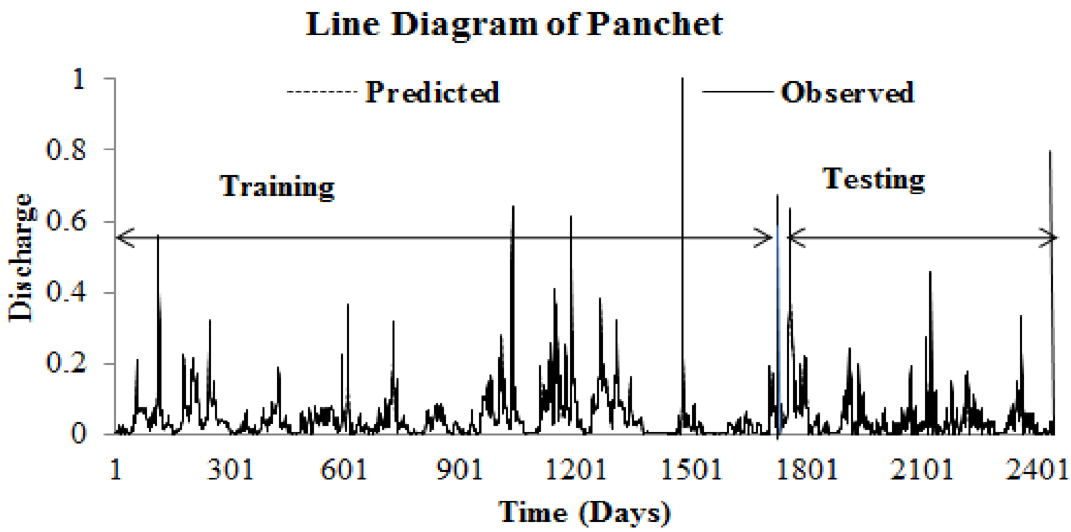
Comparison of performances of best ANFIS, Wavelet db3, Wavelet db5 & db9 models for Panchet reservoir

## VII. CONCLUSION

In this study, an attempt is made to predict the reservoir water release at multi-time step for two reservoirs by developing a reservoir release forecast model. The capabilities of adaptive neuro fuzzy inference system (ANFIS) and Different type of daubechies wavelet based ANFIS(WANFIS) model are compared for the current day, one day ahead and two-day ahead from the result obtained, it can be concluded,WAVELET- db3 in conjuction with wavelets out performed the standard ANFIS, WAVELET –db5 models and db9 models. It may be related to the ability of wavelets to handle non-linearity, non-stationary and seasonality behaviour in input time series. In this study the result obtained showed clearly that the daubechies3 based wavelet ANFIS is capable of modeling the water release more accurately, thus confirming the improvement achieved by using daubechies3 based wavelet ANFISand in many other hydrological time series applications. The result and the comparative study indicate that the daubechies3 based wavelet ANFISis more suitable to predict reservoir water release at various multi-time steps then ANFIS and other types of daubechies based models. The Daubechies Waveletbased ANFIS approach could therefore be used as a very useful and reliable accurate tool prediction and other reservoir operation studies related to water reservoir planning and management.




(a)




(b)

Figure 2 : Line diagram of predicted and observed reservoir water releases for current day using ANFIS, WANFIS and Wavelet – GP of (a) Maithon (b) Panchet reservoirs.

## VIII. ACKNOWLEDGEMENTS

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