# Impact of Climate Change on Reservoir Inflow Predictions: A Case Study

**N. Ramsundram, Nisha Khanam**

***Abstract: Hydrological cycle is inherent of climate processes with lot of interactions thereby making the system to be complex. The modeling of hydrological cycle to simulate the water resource has been well researched for more than a decade. In the recent past the studies are initiated to capture the influence of climate parameters on the hydrological cycle. One of the major inferences from the above is that,influence of climate parameters in arid and semiarid climatic region is not very significant. To understand the generalized behavior stated by the research community on arid regions, in this research paper we explored the inflow database of stanely reservoir, Tamilnadu. A modeling framework has been developed that predicts the reservoir inflow considering the future climatic scenarios. From the developed model,we inferred that the generalized stated on arid region valid only in case of regional / macro modeling, and it does not valid for specific case as micro climate variables influences the hydrological cycle.***

***Keywords: hydrological cycle, reservoir inflow, prediction, climate variables.***

## I. INTRODUCTION

One of the major storage structure in any watershed is the reservoir, the flow through the reservoir has been controlled by arrangement of sluice gates in the dam structure. The release rule curves derived for these reservoirs are based on; a) the downstream / stake holders demand, and b) Inflow received by the reservoir over the time period. The inflow received by the reservoir has two major components, namely; i) local inflow generated in the upstream catchment area, and b) release from upstream reservoir incase of multi-reservoir system. The local inflow is highly dependent on the catchment characteristics and the rainfall precipitated during the time period't'. Rainfall is a part of hydrological cycle (natural process), the quantum of rainfall depends on parameters such as temperature, humidity, wind speed, cloud formation etc. Any natural processes in a watershed is highly influenced by the changes in climatic variables and have long term impact on economic and ecological processes (USEPA, 2004). In general climate change is defined as "the difference between long-term mean values of a climate parameter or statistic, where the mean is taken over a specified interval of time, usually a number of decades" (Askew, 1987).The hydrologic cycle is a part of the climate system; the interactions between the components in the system give rise to the system complexity.

The above complex system is modelled as a) empirical model, b) water balance model, c) conceptual lumped parameter model and d) process based distributed parameter models (Leavesley, 1994). The above listed models are developed to replicate the hydrological cycle, the climate influence by considering the variability in the climate parameters. Intergovernmental Panel on Climate Change (IPCC) developed global climate model (GCM) which forecast the future climate parameters. Incorporating the parameter values from GCM in to hydrological cycle models will have the ability to visualize the impact of climate change on the system. IPCC has stated that the average global surface temperature has increased by 0.45˚C to 0.6˚C and the average sea level has increased by 15 to 20 cm during last century (IPCC 2001). IPCC has created climate scenarios such as (A1, A2, B1, B2 and their combinations) based on economic and environmental development. The potential impacts of climate change are; a) current water security problems are likely to increase by 2050, b) substantial impacts on agriculture and forestry are very likely by 2050, c) the current trends of glacial melts suggest that the snow fed rivers like Ganga, Indus, and Brahmaputra could likely become seasonal rivers in the near future and could likely affect the economics in the region (IPCC 2007). As southern and eastern Asia is concerned, climate change increases runoff, but this may not be very beneficial in practice because the increase tend to come during the wet season and extra water may not be available during dry season (Arnell 2004).

In India, precipitation has always been extremely variable, with the number of annual rainy days varying from 12 to 100 and there are rain events that have poured about 60% of the total annual precipitation within few hours. It is projected that due to climate change, the inter-annual variability of the monsoon is expected to increase. Also, the rainy days will be less with concentrated rain within few hours and increase in dry spells (Mukerji, 2009). The above said likely impact may create excessive runoff within short period, thereby reducing the groundwater recharge potentials (Mall et al., 2006). This excessive runoff in addition may influence the flooding frequency in the watershed, and also increase in dry spells may increase the frequency of drought in the watershed (Frederick, 1997).

In this case of increase in flood frequency / probability of

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frequent drought, it is required to assess the change in inflow received at the inlet of the reservoir. From the literatures and analysis of rainfall data for 131 year period, it is observed that no clear role of global warming in the variability of monsoon rainfall over India (Mall et al., 2006). Even though the above finding insist that 'no impact of considering climate parameter for India', but it is worthwhile to consider the climate parameters to quantify the potential adverse impacts on water resources that may occur in future time periods.

The aim of this paper is to show the impact of climate change on watershed development explicitly. In this paper, we proposed a methodology for inflow forecasting considering the climatic parameters for surface water reservoir (Stanely reservoir, Tamilnadu).

## II.STUDY AREA

Mettur or Stanely reservoir is one of the multipurpose reservoirs in Tamilnadu state, South India across Cauvery river (Figure 1). Mettur dam is located at 11 52'N and 77 50' E with a length of 1700 m. It has an ayacut area of 1310 sq.km for irrigation and also generates hydro electric power of 32 MW. In the recent past the landuse pattern in the reservoir catchment is subjected to massive change by urbanization. The industrial growth in the upstream of the reservoir and also in the watershed has alerted the natural flow to the reservoir. It is well known fact that release from the reservoir is more influenced by the inflow received at that time period. Being a multipurpose (irrigation and hydro power generation) the influence of inflow at that time period plays a major role on the release to be made.

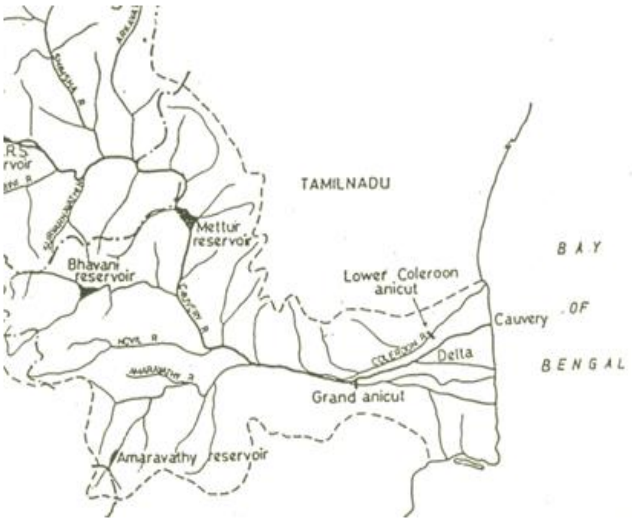


**Figure 1: Stanely/Mettur reservoir located in Cauvery river basin**

## III. METHODOLOGY

As above described in the study area, it is expected that there might be changes in the inflow received by reservoir at future time scales. There might be a chance that apart from the effluents contributing to additional discharge to inflow, the emission from industries might influence the climatic change inducing increase /decrease in climatic parameters such as temperature, humidity, wind speed and precipitation. The proposed methodology (Figure 2) is framed to analysis whether there is change in precipitation in future time scale, and also visualizing the corresponding impact on the river discharge reaching the reservoir.

The Proposed methodology couples two major components;

1. The precipitation forecasting based on climate model (GCM)
2. The reservoir inflow forecasting model

The two components are coupled (Figure 2) to forecast the future inflows to the reservoir. For this study the climate parameter (precipitation) is taken from HADCM3 GCM model as it considers vegetation in its prediction model. The climate parameter is taken for strong economic development scenario A2 as it might represent enormous carbondioxide emission which influences the local climate. The extracted climate parameter for the study area will be in a coarse resolution covering kilometers. The baseline data (historical data) prevailing in the study area is used to perform statistical downscaling of coarse resolution data to finer resolution. The finer resolution precipitation is derived for two time periods (2025 and 2050) to study the influence of climate on inflow. On the other hand to forecast the reservoir inflow, artificial neural network model (ANN) is model.

$$I_t=f(R_{t-1},R_t,I_{t-1})$$

Where Inflow at time (t) i.e., ($I_t$) is depend upon the present time period Rainfall($R_t$), Pervious time period rainfall ($R_{t-1}$) and inflow ($I_{t-1}$). The consideration of pervious time period inflow into modelling is because there might be influence of It-1 based on length of travel time taken by the discharge to reach the reservoir. The Input and the output for the ANN based inflow forecasting model is scaled in the domain [0, 1]. The estimation of parameters in ANN model defines the accuracy of the forecasted inflow time series. To ensure the accuracy on estimation of parameters in ANN (network weights), a optimization algorithm coupled to the network (Figure ). The purpose of the optimization algorithm in ANN model is to supply 'n' number of parameters for 'n' neural linkages. In our study we have used genetic algorithm (GA) for optimization parameters, GA has the ability to generate parameter range from [-inf, +inf].

Objective function:

$$minimize \left\{ \frac{\sum_{t=1}^{T} ItP - ItO^2}{\sum_{t=1}^{T} ItO - \overline{ItO}^2} \right\}$$

Constraint:$ItP \geq 0$where, $It_P$ is predicted inflow at 't' and $It_O$ is the observed inflow at 't'. This optimization coupled ANN gives the optimal set of parameters from the training process. The optimized network with parameters is used as reservoir inflow forecasting model for simulating the inflow time series for given downscaled 2025 and 2050 precipitation.

## IV. RESULTS AND DISCUSSION

The precipitation/rainfall forecast for the years 2025 and 2050 are taken from HADCM3 for scenario A2 and



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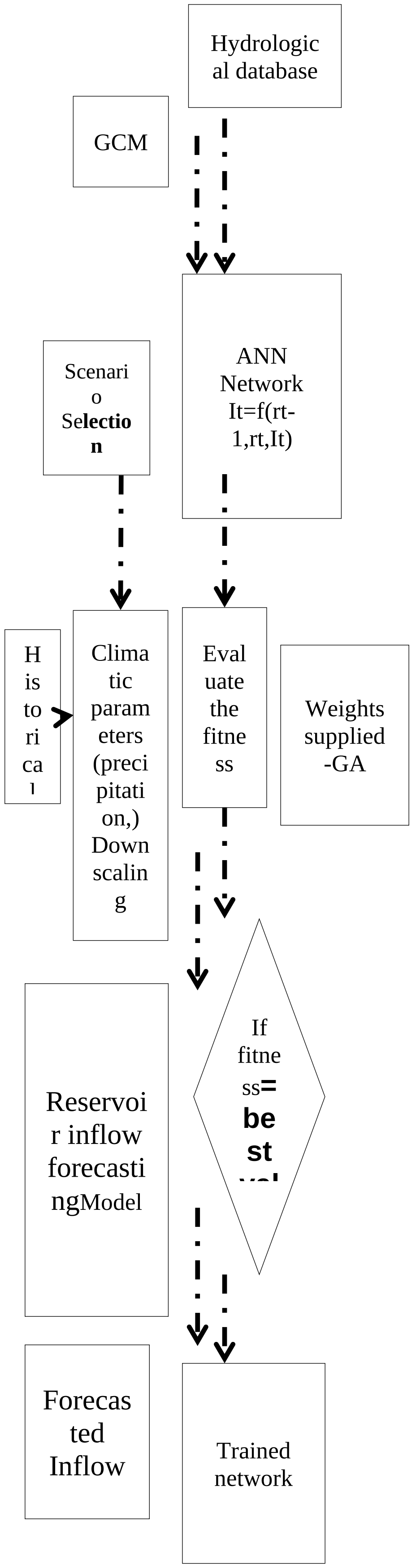


**Figure 2: Reservoir inflow forecasting model with influence of climate parameters**

downscaled to the study area grid. Figure 3 shows the downscaled precipitation for those years with the current rainfall. When we look into the annual rainfall volume, the precipitation quantity has reduced by 0.1% and 7% during 2025 and 2050 respectively. But in a closer look, it can be seen from rainfall hyetograph that monsoon season has shifted towards right and dry spell has increased during November and December.

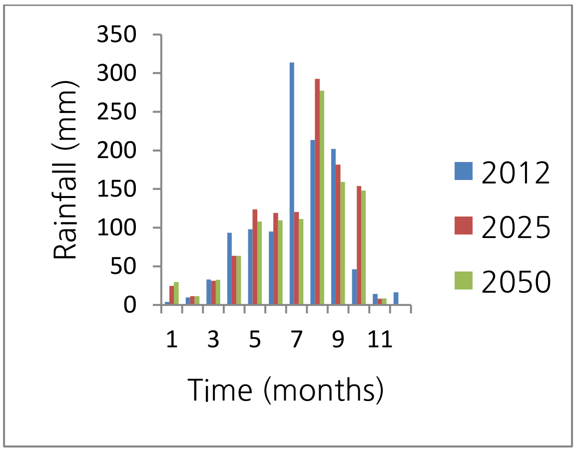


Figure 3: Forecasted rainfall for year 2025 and 2050

The historical rainfall database is used to train the ANN-GA reservoir inflow forecasting model. 80% of the historical database is used for training the model and 20% is kept for validation. To evaluate the performance of training and validation, Nash-Sutcliffe efficiency is incorporated into the model. It is observed that nash efficiency for training is 0.90 (Figure 4) and for validation, 0.85.The trained model is fed with the forecasted rainfall for the respective years to derive the inflow to the reservoir (Figure 5).

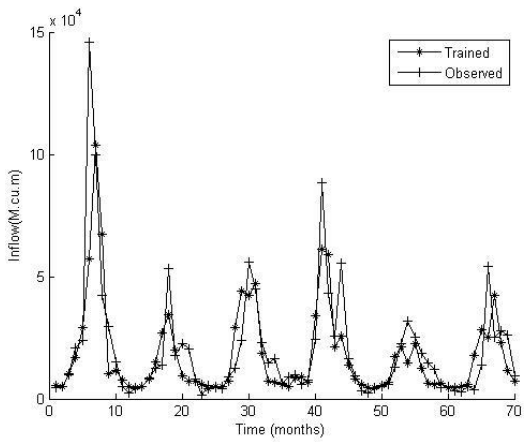


**Figure 4: Prediction of inflow series by the ANN GA model in training phase**

Similar pattern as such of rainfall is observed in the forecasted inflow i.e., the annual inflow volume during year 2025 has reduced by 5% and for year 2050 it has reduced by 14% compared to annual volumes of year 2012. And also shift of runoff peak also can be observed similar to rainfall.


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From figure 5 it can also be inferred that there is chance of increase in frequency of drought period of July. And also it can also be seen that over all runoff to reservoir during monsoon period have reduced, that may likely affect the release during month of December and January. The pattern of reduction in annual inflow (2025 and 2050) to reservoir conveys a strong indication that reservoir may become dry in mere future. The above result shows that there is a dramatic impact of climate parameters on the inflow to the reservoir.

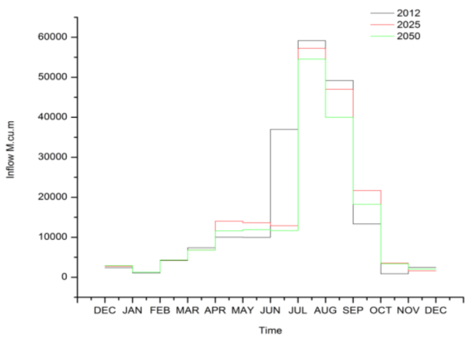


**Figure 5: Comparison of forecasted inflow for years 2025 and 2050 with present scenario.**

## V.CONCLUSION

The influence of climate parameters in the complex hydrological cycle plays a major role in water resource development. Many earlier works have reported that, in semi arid and arid climatic region the influence of climate parameters are not influencing the hydrological cycle to significant level. Even though, it is worth to consider the climate parameters for modeling of water resource system. Through the casestudy on reservoir inflow forecasting considering climate parameter, we observed that there is influence of climate parameter on the inflow received by the reservoir. The reliability on the results derived is subjective based on the knowledge of modeler about the study area. As the proposed methodology have not considered the uncertainty associated with the climate model (GCM) in forecast of rainfall. And also the data driven model (ANN-GA) which is used for reservoir inflow forecasting also carry lot of uncertainties on the forecasted inflow. In general, even though uncertainties associated with the models are not considered, the proposed have the ability to capture the influence of climate parameters in the reservoir inflow. This forecasted inflow for the years 2025 and 2050 gives an overall picture to the reservoir operator to plan for optimal operation to cope up with the variability in the inflow.

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