Qualitative and Quantitative Prediction of Reservoir Inflows during Monsoon Season

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Introduction

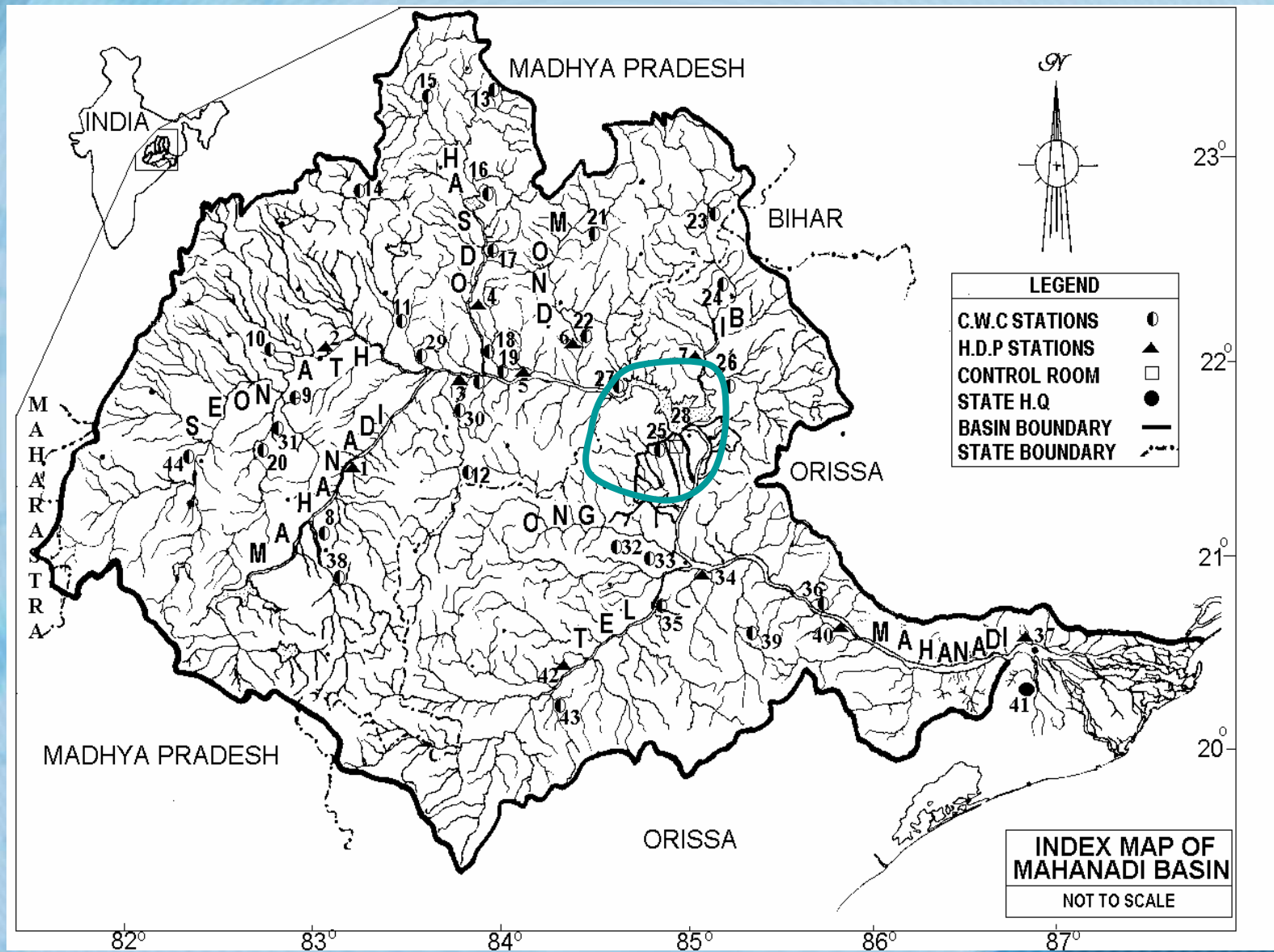
- Need for inflow forecasting
  - Reservoir operation
  - Monsoon flows
    - More than 75% flows occur during monsoon
    - Uncertainty
      - Date of onset
      - Duration
      - Temporal distribution
- Short term vs long term forecasting

Mahanadi River Basin

- The Mahanadi, literally meaning the great river, is the largest river flowing through the State of Orissa. It is one of the major river basins in the eastern region of India covering the states of Madhya Pradesh, Maharastra, Bihar and Orissa.

- The total basin is bound by Central Indian hills on the north, Eastern ghats on the south, Bay of Bengal on the east and Maikela range on the west.

Basin Map of River Mahanadi



Location

- The Mahanadi basin lies between 80°-30′ E to 86°-50′ E longitude and 19°-20′ N to 23°-35′ N latitude. The river drains an area of 141,600 km^2 before discharging into Bay of Bengal.
- Before the construction of Hirakud dam, it caused devastating floods at regular frequencies at its lower deltaic plains in the coastal districts of Cuttack, Puri, Khurda, Jagatsinghpur and Kendrapara.

Features of the Reservoir

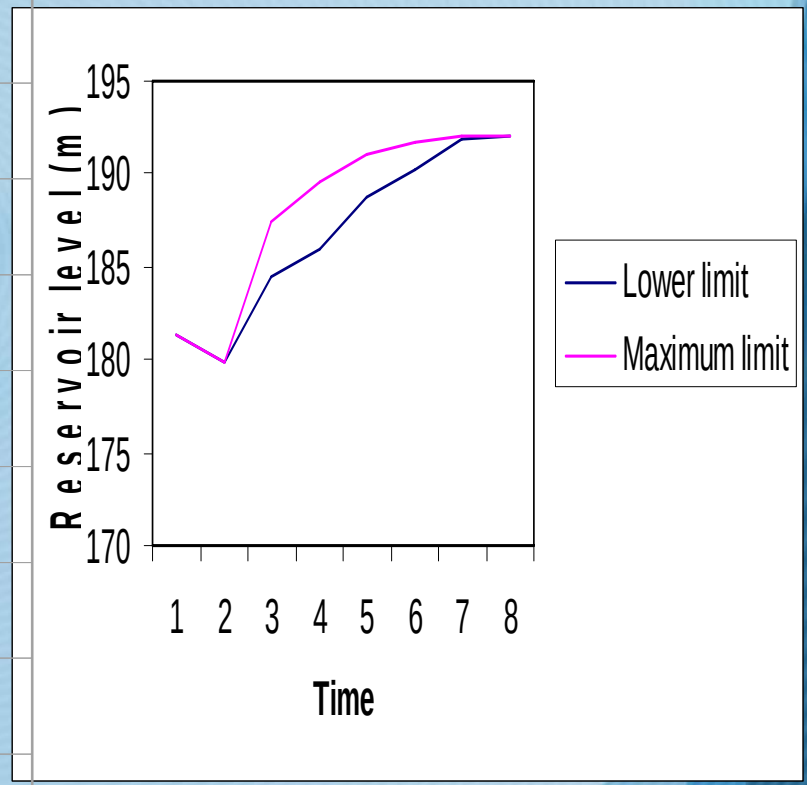
- i. Top of the Dam : R.L. 195.680 m
- ii. F.R.L./M.W.L. : R.L. 192.024 m
- iii. Dead Storage Level : R.L. 179.8 m.
- iv. Gross Storage capacity : 7196.7 Mm^3
- v. Dead Storage capacity : 1816.4 Mm^3
- vi. Live Storage capacity : 5818 Mm^3
- vii. Water spread area at F.R.L. : 743 km^2
- viii. Water spread area at DSL : 274 km^2

Features of the Reservoir

- Irrigation
  - Kharif (June-Oct) – 155,635 ha
  - Rabi (Nov – Feb) – 108,385 ha
- Hydropower
  - Two power house
  - Total installed capacity – 307.5 MW
- Flood Protection to 9,500 sq.km. delta region

Prevalent Rule Curve

Date	Recommended level (m)	
	Lower limit	Maximum limit
Upto 1st July	181.356	181.356
Upto 1st August	179.832	179.832
Upto 11th August	184.404	187.452
Upto 21st August	185.928	189.586
Upto 1st September	188.671	191.109
Upto 11th September	190.195	191.719
Upto 21st. September	191.872	192.024
Upto 1st October	192.024	192.024



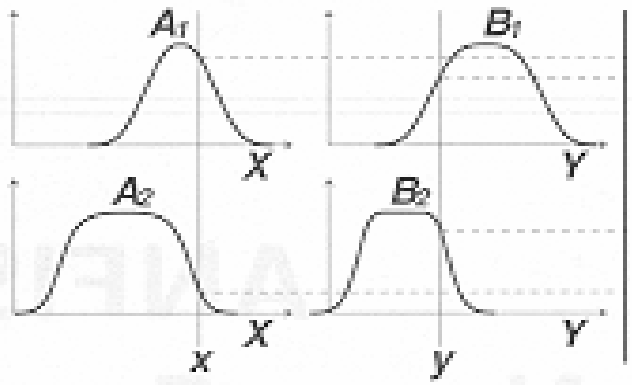
Characteristics of Neuro-Fuzzy Systems

- A neuro-fuzzy system is a fuzzy system that is trained by a learning algorithm derived from neural network theory
- The learning process is not knowledge based, but data driven
- A neuro-fuzzy system can be viewed as a special multi-layered feed forward neural network
- A neuro-fuzzy system can always be interpreted as a system of fuzzy rules
- It is possible to create the system from scratch by learning from data
- It is possible to initialise the system by prior knowledge in form of fuzzy rules

Characteristics (Contn'd)

- The learning procedure of a neuro-fuzzy system takes the semantic properties of the underlying fuzzy system into account
- A neuro-fuzzy system approximates an multi-dimensional function that is partially given by the training data
- The fuzzy rules encoded within the system represent vague samples
- There are several neuro-fuzzy approaches to find fuzzy systems by learning – e.g. ANFIS, NEFCLASS, NEFCON, GARIC, Fuzzy RuleNet, FuNe …)

ANFIS

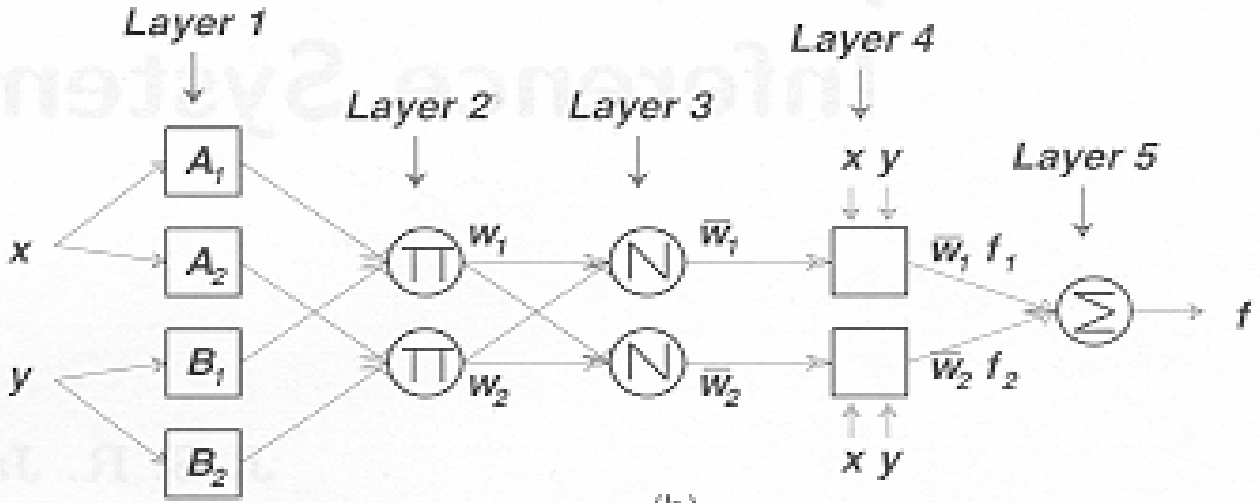


w_1 $\quad f_1 = p_1x + q_1y + r_1$

w_2 $\quad f_2 = p_2x + q_2y + r_2$

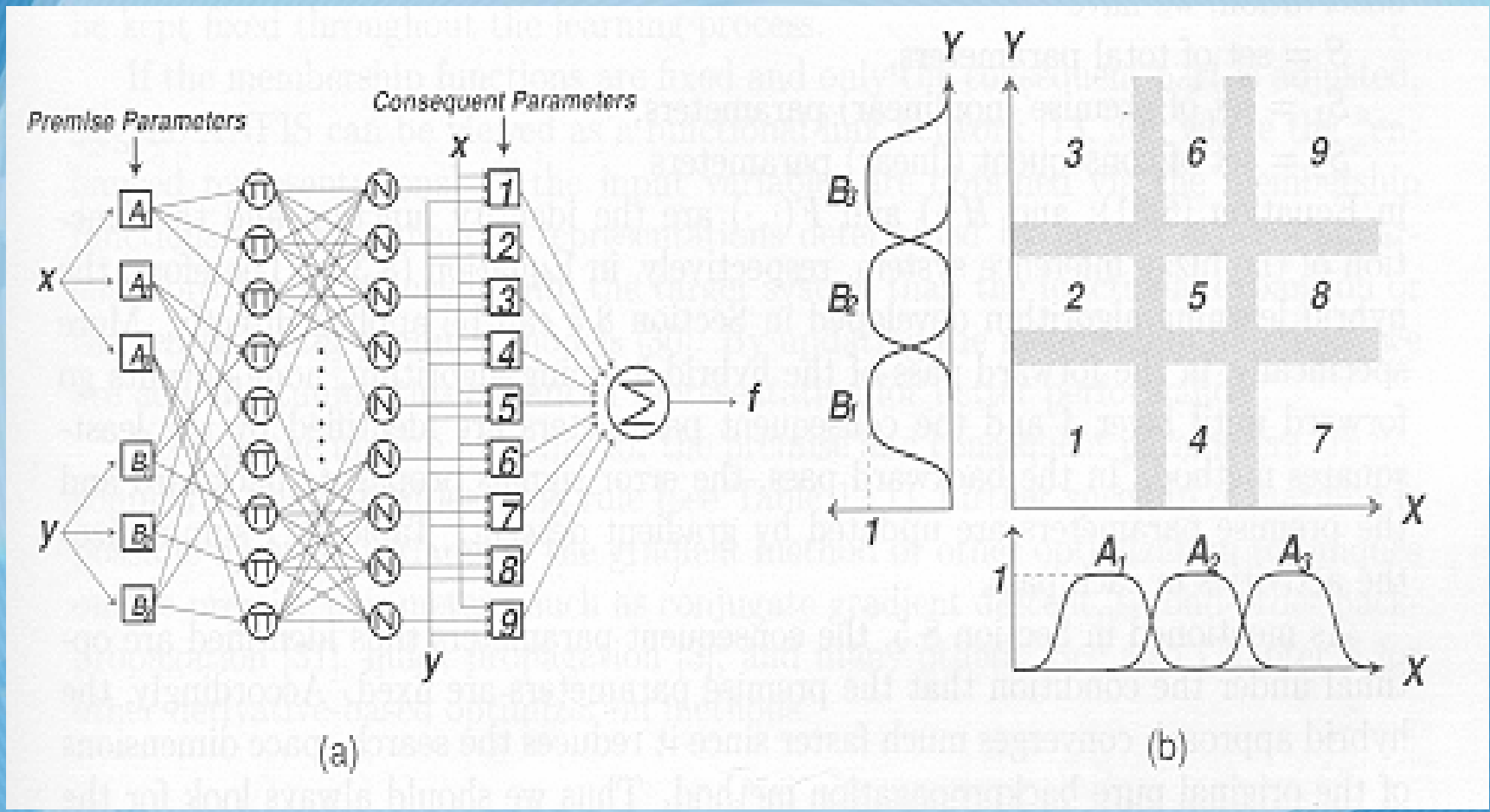
$$f = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2} = \bar{w}_1 f_1 + \bar{w}_2 f_2$$

(a)



(b)

Parameters in ANFIS



Qualitative Description of Monsoon Flows

- Classification of a year
  - Wet year – Total monsoon flow is greater than 30,800 Mm^3 (25 MAF)
  - Low flow year – Total monsoon flow less than 22,200 Mm^3 (18 MAF)
  - Medium flow year – Monsoon flow between 22,200 to 30,800 Mm^3
- This classification is significant in planning the operation of the reservoir

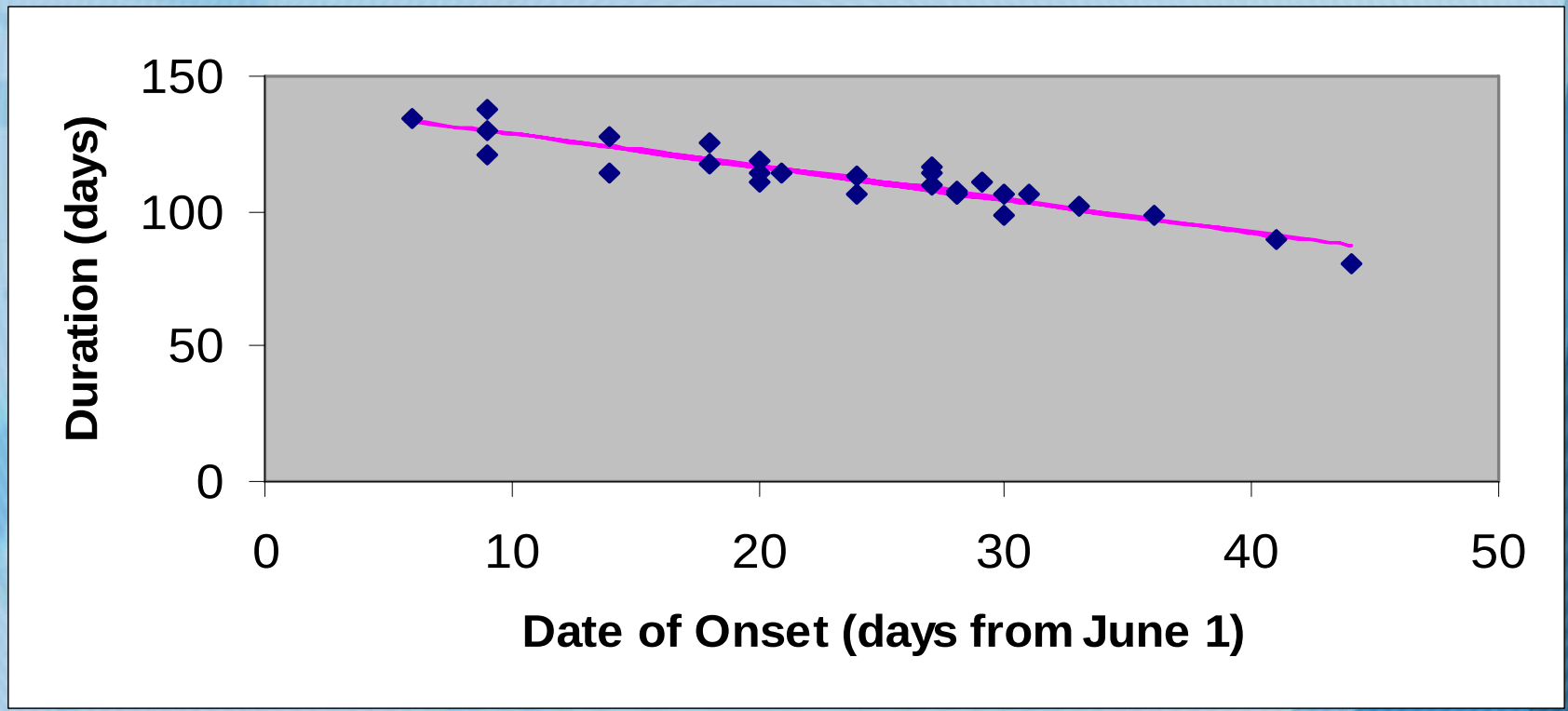
Characteristics of Monsoon

- Monsoon inflows into the reservoir depend on the date of onset of monsoon and duration of monsoon
- Normal date of onset of monsoon – June 21st
- Normal duration of monsoon – 133 days (upto October 31st)
- Date of rise of reservoir level is considered as a representative of the date of onset of monsoon

Qualitative Forecast of Inflows

- Relation between date of onset of monsoon and duration of monsoon

$y = -1.212*x + 140.92$ ($R^2 = 0.86$)



Qualitative Forecast of Inflows

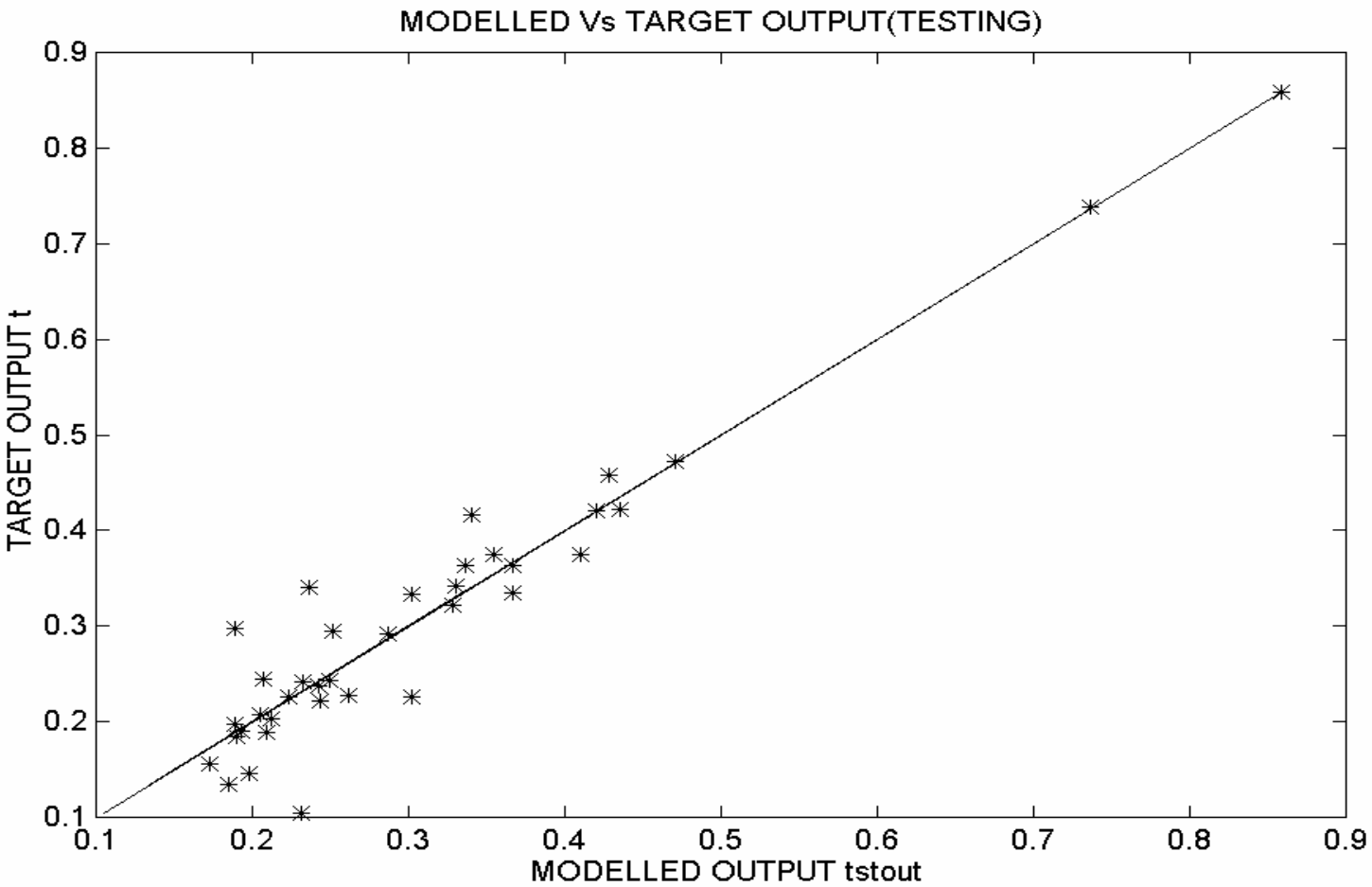
- Correlation between duration of monsoon and total monsoon inflows (based on 37 years of observed data) – 0.66
  - Duration < 100 days – low flow year
  - Duration > 118 days – wet year
  - Duration between 100 and 118 days – medium flow year
- Based on the date of onset of monsoon the qualitative forecast of the inflows for the year can be made

Forecast of Inflows – Model 1

- ANFIS Model for forecasting total monsoon flow based on the flows observed upto 20% of the duration of monsoon
  - Two inputs – flows observed upto 10% and 20% of duration of monsoon
  - 25 years of observed data used for training the model and 12 years used for testing the model
  - Each input classified into three fuzzy intervals with three parameter generalized bell function as membership function

Performance of Model 1

- Two Inputs (10%,20%)
- Corr. coef. = 0.9590

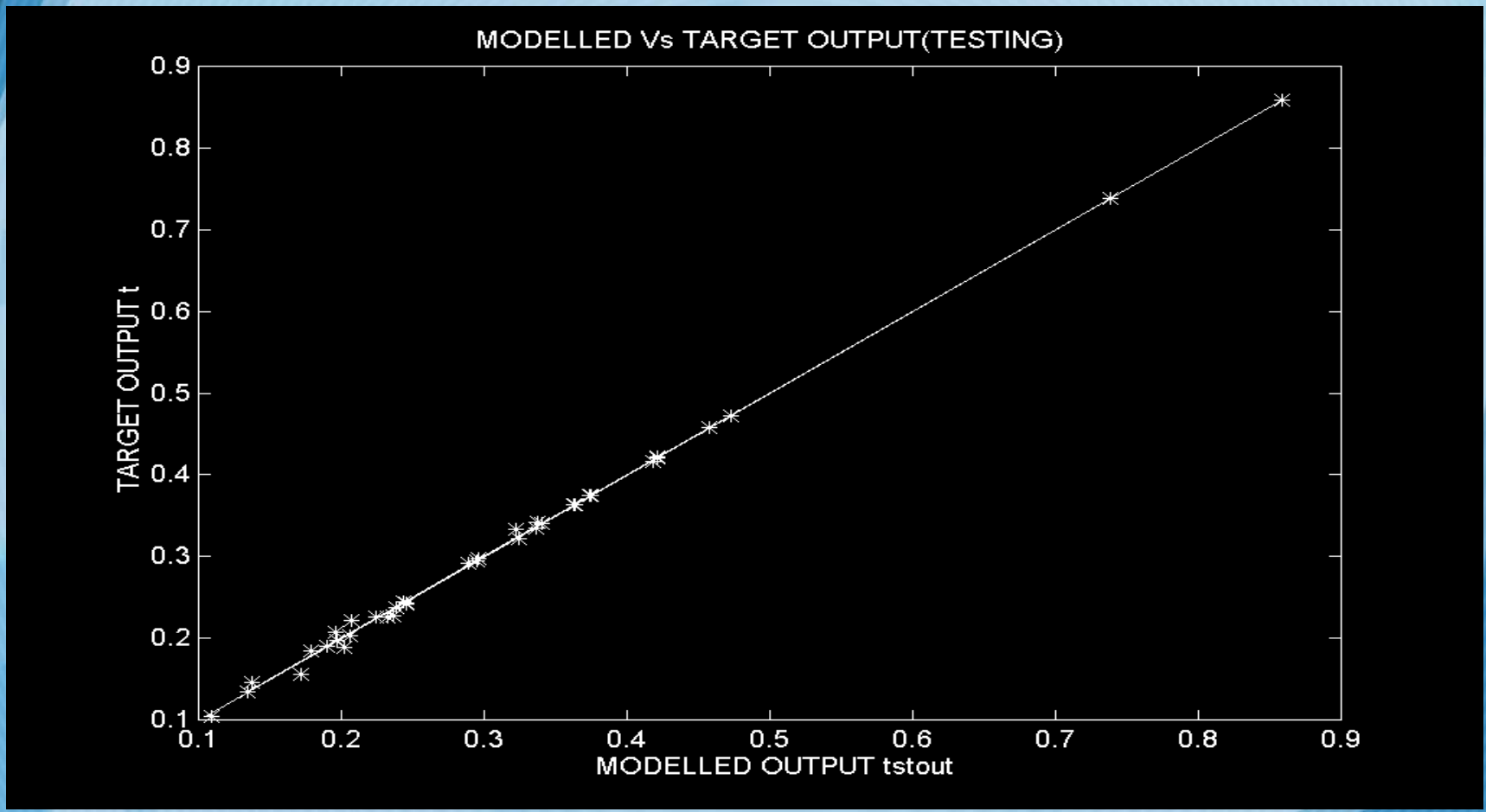


Forecast of Inflows – Model 2

- ANFIS Model for forecasting total monsoon flow based on the flows observed upto 30% of the duration of monsoon
  - Two inputs – flows observed upto 10%, 20% and 30% of duration of monsoon
  - 25 years of observed data used for training the model and 12 years used for testing the model
  - Each input classified into three fuzzy intervals with Gaussian membership function

Performance of Model 2

- Three inputs(10%, 20% , 30%)
- Corr. Coef.=0.9993



Application of the Model

- The starting date of rise of reservoir level after the onset of monsoon, is observed.
- The duration of monsoon inflow is found using regression model which gives an idea about the type of year.
- The cumulative inflows observed at 10% and 20% of the duration of monsoon are collected. With this information, the model 1 gives the cumulative flow at 100% duration as the output.
- Once 30% of the duration is reached, the value is checked. The forecast is updated by putting the cumulative flow up to this period i.e. 30% duration, in Model 2