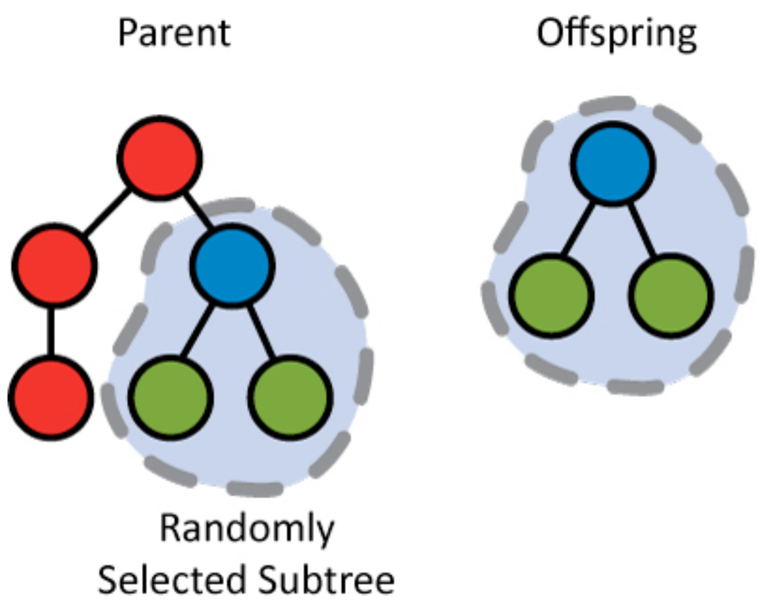
Genetic programming approach on evaporation losses and its effect on possible future climate change for Pilavakkal reservoir scheme



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Introduction

- Climate change is a major problem
- Emission of CO_2 into the atmosphere will increase the global temperature known as global warming (IPCC, 2001)
- Directly affects evaporation losses along with other climatological parameter
- Thus, the modeling should be carried out with utmost care for the possible reduction in evaporation losses due to climate change

Estimation of Evaporation

- Least satisfactorily explained components of the hydrologic cycle
- Estimation is based on mass transfer, energy budget methods
- The National Weather Service class “A” pan is the most widely used as evaporation instrument
- These methods are generic such an approach may effect the modeling approach
- Hence, it needs suitable improved modeling approach which includes necessary climatic variables

Objective

- To develop Genetic Programming(GP) by considering suitable mathematical parameter and necessary climatic variables
- To verify GP potential using Thornthwaite method
- To forecast the climatic variables using Markovian chain series methods
- To estimate the future evaporation using developed Genetic Programming for the possible climate change studies

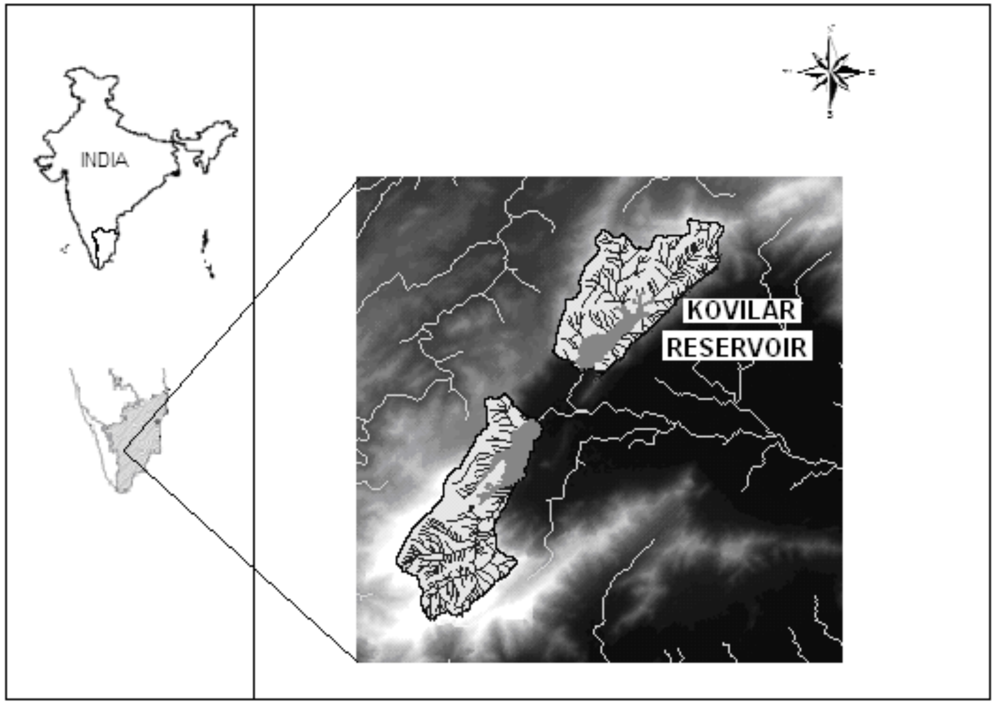
Study area

- Pilavakkal reservoir system consists of Periyar and Kovilar reservoir in Viruthunagar District, India

- Kovilar reservoir has been taken as a study area

- Located in (9°41'N, 77°23'E) and (9°38'N, 77°32E)

- Single purpose (Irrigation) reservoir



- It experiences tropical climate throughout the year

Data Used

- Mean monthly temperature varies from 20.04^{o}C in January to 38.34^{o}C in May
- Mean annual rain fall of the dam site is 1187 mm
- Historical records of hydro meteorological variables
  - Temperature
  - Wind velocity
  - Relative humidity
  - Evaporation
  - Sunshine hour
- Data is collected from Kavalur meteorological station from 1992-2000

Genetic Programming

- Automatic programming to solve the problems
- Applied to model structure identification problems
- Approximate the equation in symbolic form, that best describes how the output relates to the input variables
- Uses the concept of Darwin's "***survival of the fittest***"
- Start with initial population of randomly generated programs

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- Useful individual (Best fit) characteristics passed → next generation
- ***Crossover*** and ***Mutation*** occur in reproduction
- Less fit individual, discarded
- Final output of the model consists of independent variables and constants
- Choices of operators depend upon the degree of complexity of the problem

Model development with GP

$$E_{t\,comp} = f\,(T_t,\ RH_t,\ Nh_t,\ V_t,\ E_{t\,obs}) \qquad (1)$$

where,

$E_{t\,comp}$ = Computed Evaporation losses at time t (Mm^3)

$E_{t\,obs}$ = Observed Evaporation losses at time t (Mm^3)

T_t = Temperature at time t (ºC)

RH_t = Relative Humidity at time t (%)

Nh_t = Sunshine hour at time t (Hours/day)

V_t = Wind velocity at time t (Kmph)

Contd….

The mathematical models evolved from GP are presented in equation as,

$$E_t = \left(\cos\left\{ T_t \left[\sin\left(\frac{-1}{0.107V_t} \right) - RH_t \right] \right\} \right)^2 * V_t * T_t \qquad (2)$$

- almost all given input parameters affect the system
- temperature term appears explicitly
- prediction is found to be better in the zone of mean of evaporation values i.e. about $0.04 Mm^3$

Thornthwaite model

It is used to verify the potential of GP and it is explained as follows:

The Thornthwaite's empirical equation is:

$$PE = 16\left(\frac{10t}{I}\right)^{a} \quad (3)$$

where,

PE = Potential evapotranspiration in centimeter per month.

t = Mean monthly air temperature (ºC)

Contd….

i = the monthly heat index and it is expressed as:

$$i = \left(\frac{t}{5}\right)^{1.514} \tag{4}$$

I = Annual heat index and it is given by the equation:

$$I = \sum_{j=1}^{12} i \tag{5}$$

j = 1, 2, 3 ...12 is the number of the considered months.

$$a = 6.7 * 10^{-7} I^3 - 7.7 * 10^{-5} I^2 + 0.018I + 49 \tag{6}$$

Markovian model

- It preserves the statistical properties
- It is used to forecast the value

The following equation represents m[th] order Markovian model.

$$q_i = b_0 \underbrace{+ b_1 q_{i-1} + b_2 q_{i-2} + \ldots\ldots\ldots\ldots + b_m q_{i-m}}_{\text{deterministic part}} \underbrace{+ e_i}_{\text{random part}} \qquad (7)$$

Contd….

The meteorological parameters are forecasted using the below equation:

$$y_{t+1} = \bar{y}_t + \frac{\sigma_t}{\sigma_{t-1}} r_{(t-1)-t}(y_{t-1} - \bar{y}_{t-1}) + e\sigma_t \sqrt{1 - r^2_{(t-1)-t}} \quad (8)$$

where,

y_{t+1} = forecasted value at time (t+1)

$\bar{y}_t$ = average of actual value at time (t)

y_{t-1} = actual value at time (t-1)

$\bar{y}_{t-1}$ = average of actual value at time (t-1)

σ_t = standard deviation at time (t)

σ_{t-1} = standard deviation at time (t-1)

r = correlation coefficient between time series (t) and (t-1)

e = random part, rectangularly distributed (0, 1)

Results and Discussion

- Variable T_t, RH_t, V_t appears in equation 2
- Temperature directly affects the system
- Wind velocity term indicates that the study area don't have obstruction
- Relative humidity depends on absolute pressure of the system
- Sunshine hour indirectly indicating in the form of temperature
- Trigonometrical function shows that there is a chance for seepage

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Table 1-Performance evaluation of static GP and Thornthwaite model

Model	Model performance in different period			
	Training (1992-1997)		Testing (1998-2000)	
	CC (%)	CE (%)	CC (%)	CE (%)
GP	88.7	77.4	84.3	73.9
Thornth waite	73.1	68.5	67.0	61.3

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Genetic Programming approach on Evaporation Losses

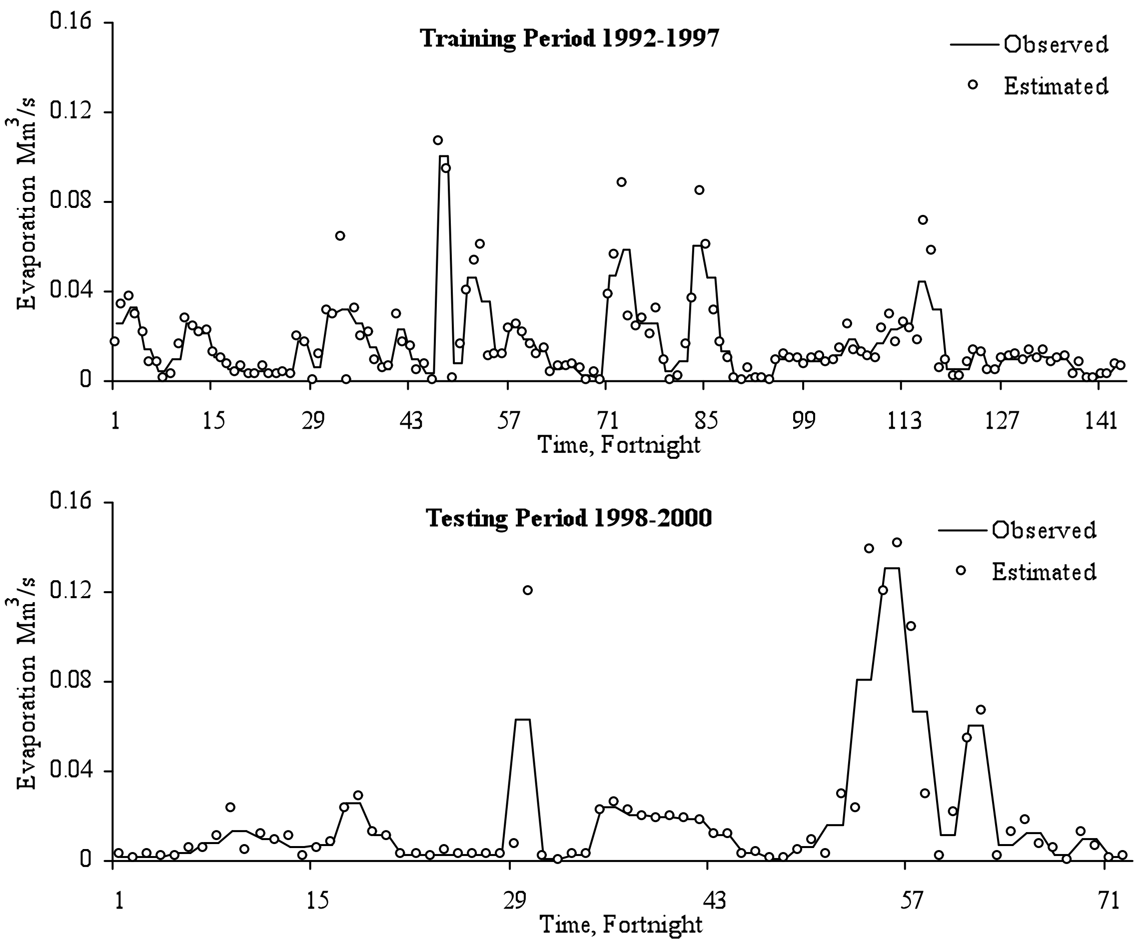

Figure 2 - Observed and estimated evaporation by GP model

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Table 2-Forecasting of temperature using Markovian chain series analysis

No	Time series	Length of record	Annual Mean Value in °C	Inc. in actual value from base period in °C	Inc. in %
1	1992-2000	9	29.08 (2000)	----	----
2	2001-2025	25	30.17 (2025)	1.09	3.75
3	2026-2050	25	31.22 (2050)	2.14	7.35

*(Annual mean value at a particular time period)

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Table 3-Prediction of evaporation using Genetic Programming modeling approach

No	Time series	Length of Record	Annual Mean Value in m^3x10^3	Inc. in actual value from base period in m^3x10^3	Inc. in %
1	1992-2000	9	30.90 (2000)	----	----
2	2001-2025	25	34.30 (2025)	3.40	11
3	2026-2050	25	36.13 (2050)	5.23	17

*(Annual mean value at a particular time period)

Conclusion

- GP has good potential to fix the non-linear effects
- GP model gives better performance than Thornthwaite model
- Not applicable outside of this environment
- Offers obvious advantages over the general evaporation models
- Better choice for regional model for climate change prediction
- This can be coupled with General Circulation Models (GCMs) to predict the global climate change

Thank You

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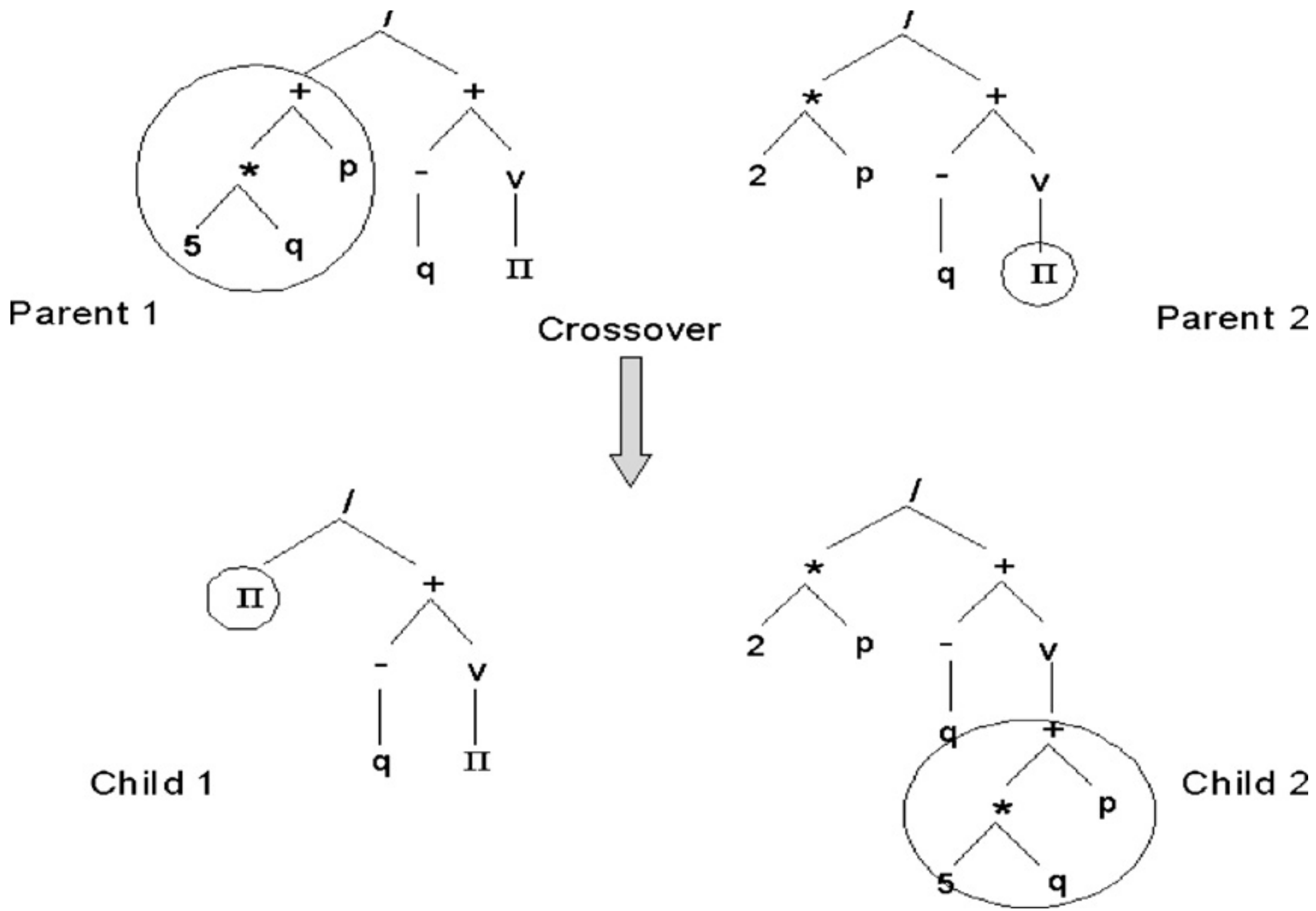
Crossover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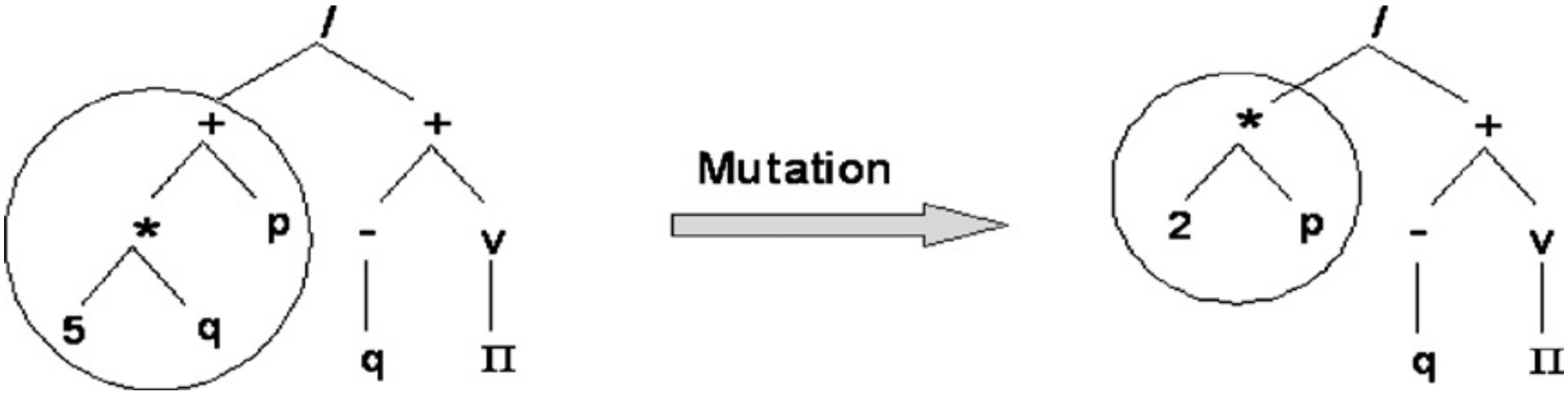
Mutation



Ref:Surabhi & Deo (2008)