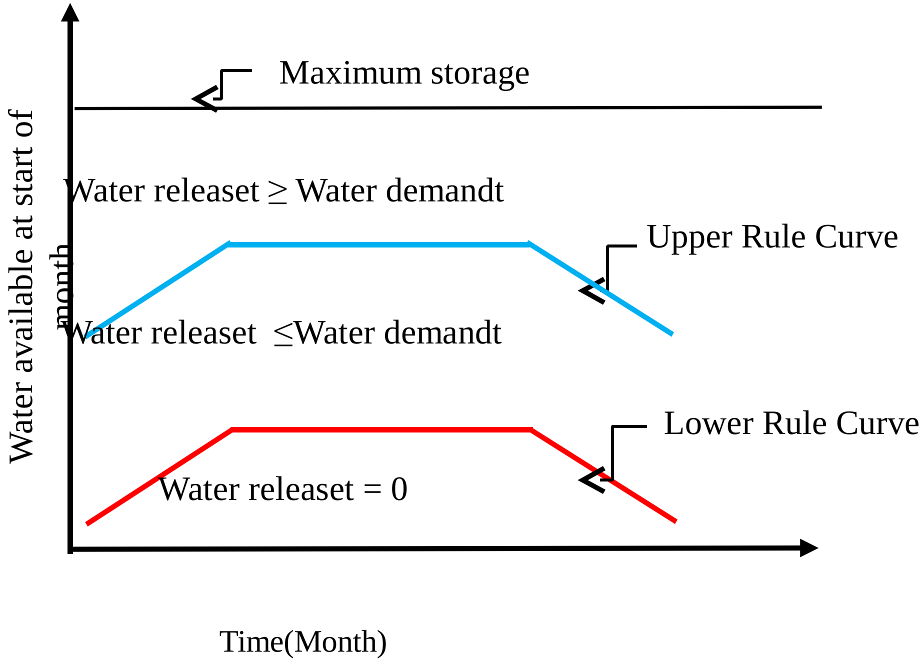
New Dynamic Genetic Algorithms for Optimising Reservoir Operating Rule Curves

C. Chiamsathit, A. J. Adeloye & B. Soundharajan
Heriot-Watt University, UK

Reservoir operation



Distinctly Global
www.hw.ac.uk

Optimising reservoir rule curves: Genetic algorithm

Genetic algorithms (GA) optimisation has long been recognized, and widely applied, to provide the optimal solutions when deriving reservoir operating policies. It was accepted that GA increased the efficiency of the water supply performance (Chang et al., 2005).

Optimising reservoir rule curves:
Challenge in GA

Standard GA (SGA), however, often fails to search adequately for the global optimum, especially when the search space is either too wide or too narrow.

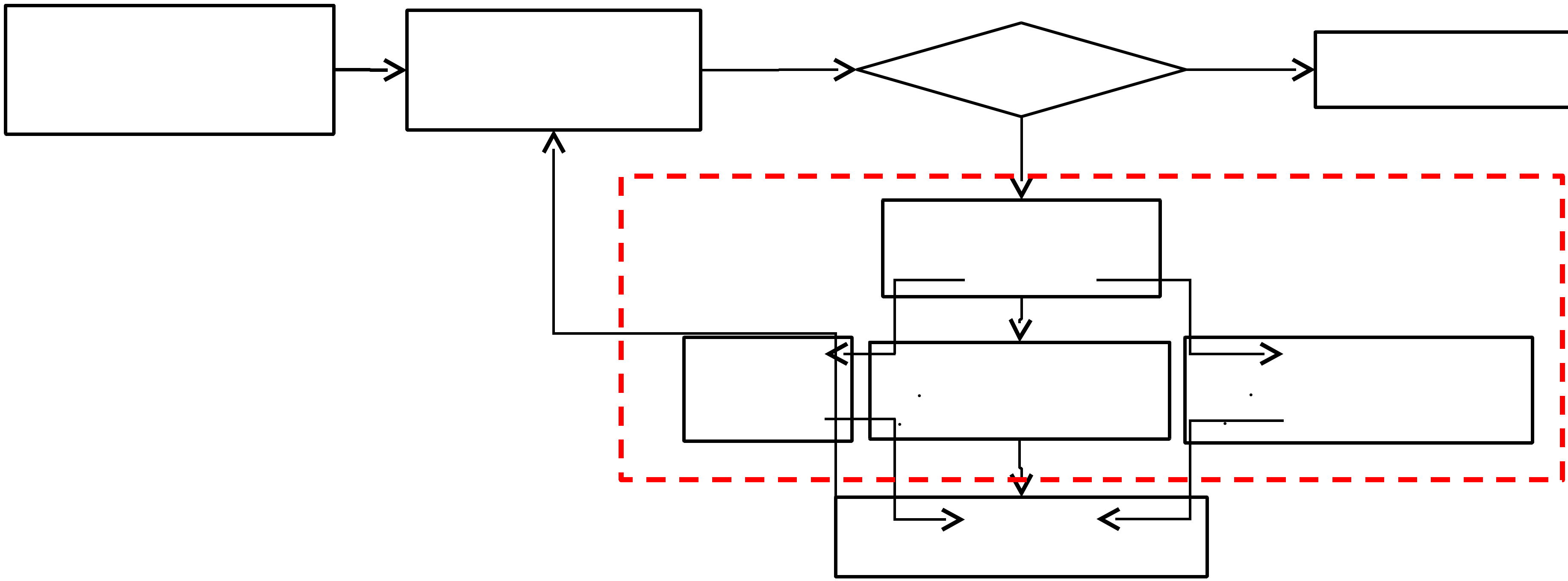
Aim & Objectives

Aim: To present a new development of the GA, known as the dynamic GA (DGA) that is more efficient than the standard GA (SGA) and represents an improved SSRT in arriving at an optimal solution.

Objectives:

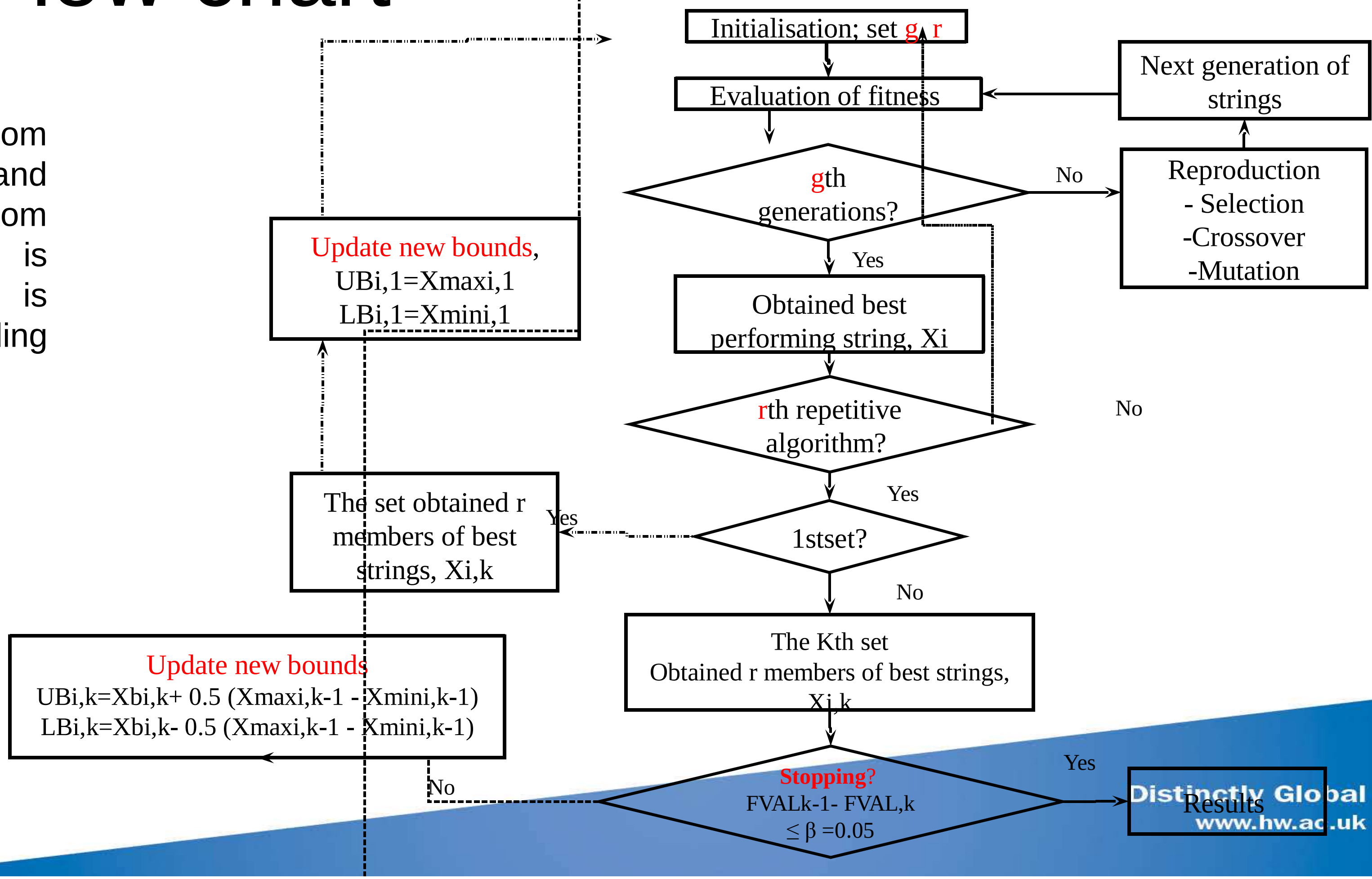
- Review the literature dealing with the deployment of GA in reservoir optimisation
- Present the development of the new DGA optimisation and discuss its main features that distinguish it from the SGA.
- Apply both the SGA and DGA to the optimisation of rule curves for the operation of the Ubonratana multi-purpose reservoir in Thailand.

Standard Genetic Algorithm (SGA): Flow chart



Dynamic Genetic Algorithm (DGA): Flow chart

It starts with an initial random population like the SGA and runs over "g" generations from which the best string is selected. This process is repeated "r" times, thus leading to "r" best strings.



$$Minimise \sum \left(D_t - D'_t\right)^2 \quad \forall D'_t \le D_t$$

$$S_{t+1} = (S_t(1-0.5ae_t) + Q_t - D'_t - be_t)/(1+0.5ae_t)$$

$$WA_t = S_t + Q_t$$

$$FCRC \ge URC_m \ge LRC_m \ge MinWL$$

$$WA_t \ge URC_m$$

$$D'_t \ge D_t$$

$$D'_t = S_t + Q_t - E_t - URC_m$$

$$Y_t = D'_t - D_t$$

$$LRC_m < WA_t < URC_m$$

$$D'_t \le D_t$$

$$Y_t = 0$$

$$WA_t - D_t \ge LRC_m, D'_t = D_t$$

$$WA_t - D_t < LRC_m, D'_t = WA_t - LRC_m$$

$$WA_t \le LRC_m$$

$$D'_t = 0$$

Reservoir Performance Indices

- Time-based Reliability (*Rt*)

$$R_t = N_s / N$$

- Volume-based Reliability (*Rv*)

$$R_v = \sum_{t=1}^{N} D_t' \Big/ \sum_{t=1}^{N} D_t$$

- Resilience (*φ*)

$$\varphi = \frac{1}{\left(\frac{f_d}{f_s}\right)} = \frac{f_s}{f_d}$$

- Vulnerability (*η*)

$$\eta = \frac{\sum_{t=1}^{f_d} [(D_t - D_t')/D_t]}{f_d}; t \in f_d$$

- Sustainability index (*λ*)

$$\lambda = \left(R_t \varphi (1-\eta)\right)^{1/3}$$

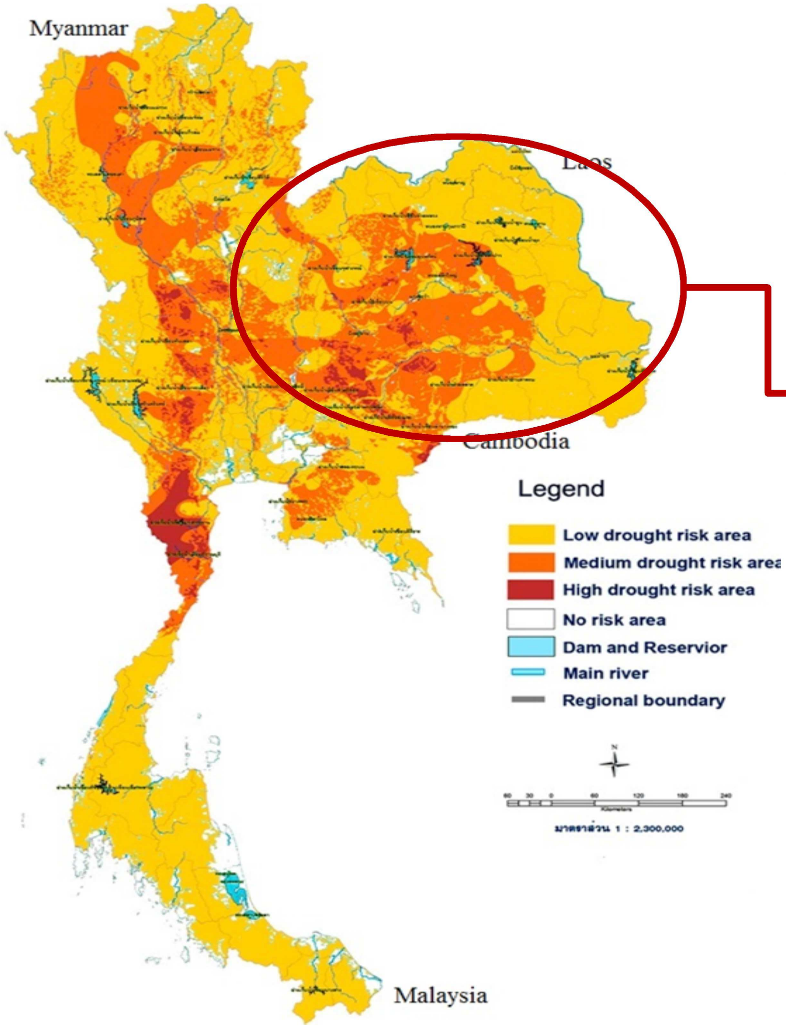
- Group sustainability index (*λG*)

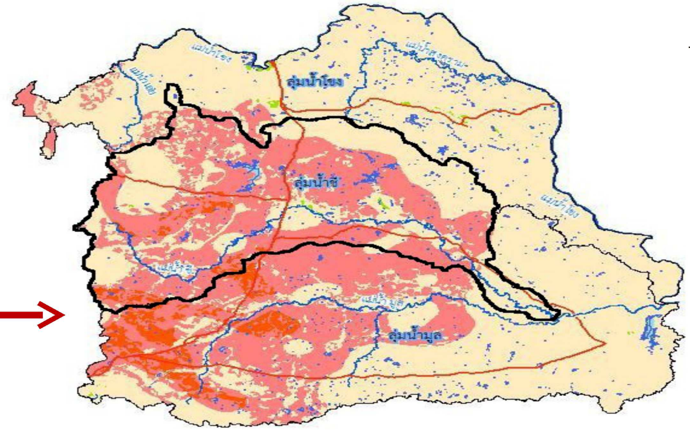
$$\lambda_G = \sum_{j=1}^{M} w_j \lambda_j$$

where

$$w_j = \frac{D^j}{\sum_{j=1}^{M} D^j}$$

Northeastern Thailand





General data of the Ubonratana reservoir

Hydrometeorological data	
Catchment area (km2)	12,000
Rainfall (mm/y)	1,200
Inflow (Mm3/y)	2,619
Public demands (Mm3/y)	12
Irrigation (Mm3/y)	706
Downstream requirements (Mm3/y)	224

Reservoir physical data	
Reservoir capacity (Mm3)	2,431
Active storage (Mm3)	1,850
Min.WL (Mm3) for Hydropower	581
Min.WL (m msl) for Hydropower	175
Min.WL (m msl) for Irrigation	168
Max.WL (m msl)	186
NWL (m msl)	182

.

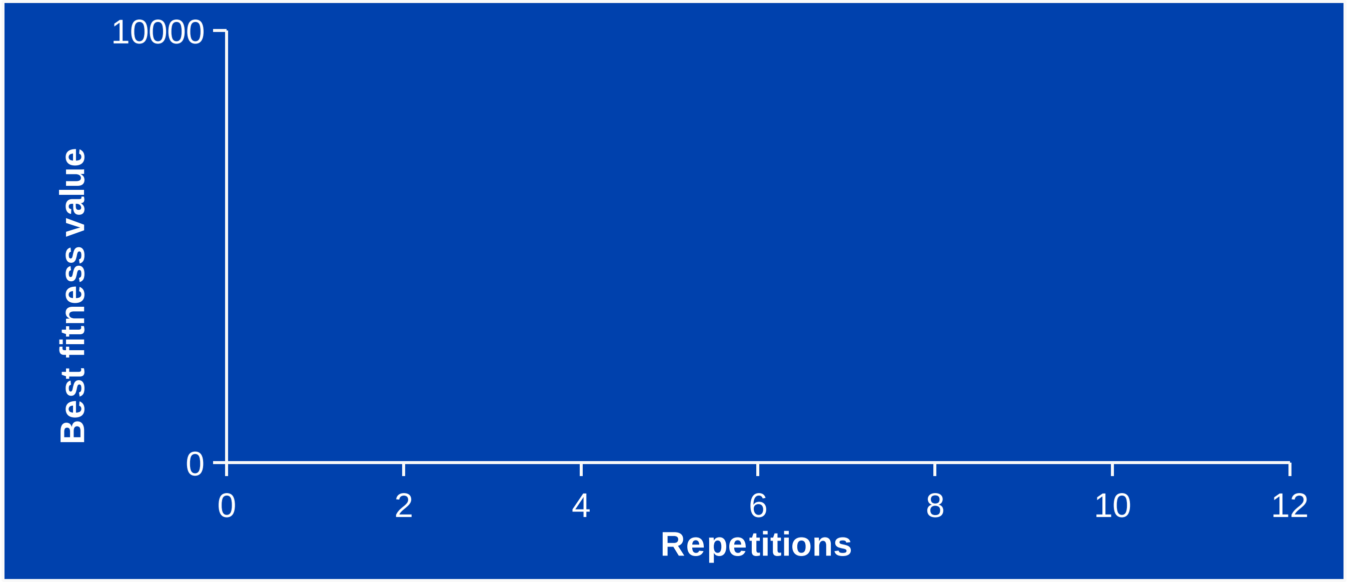
.

Results: Influence of the population size and the number of generations on GA's performance

Generations	100	1500	3000
Fitness value	18569	15809	15762

A population size of 200 and 1500 generations are the best combination.

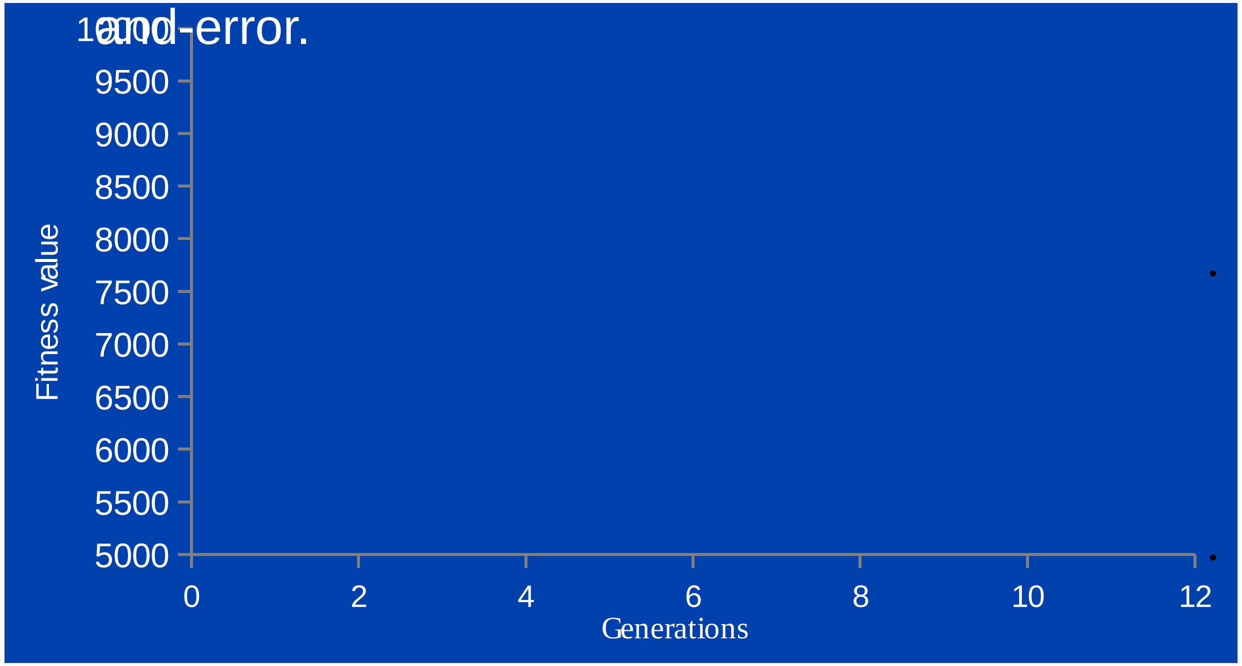
Results (Cont'd): The fitness values of the algorithm of 30 repeating times in SGA



HERIOT WATT UNIVERSITY

Results (Cont'd): Influence of the generations and repetitive algorithm on the fitness value in DGA

and-error.



"g"=2 and "r"=7 represent the best combination

Results (Cont'd): Optimised monthly rule curves

Policy	Rule Curve	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
	FCRC	1662	1616	1571	1536	1527	1527	1902	1902	1852	1804	1756	1709
SGA	URC	1141	1176	991	846	946	1340	1808	1901	1746	1366	1216	1556
	LRC	583	582	592	626	606	824	947	889	962	806	724	651
DGA	URC	1246	941	888	833	946	1423	1750	1750	1750	1422	1098	991
	LRC	583	582	582	603	582	625	961	911	848	783	714	651

Results (Cont'd): Reservoir performance

Indices/ Water user	SGA			DGA		
	Public	Downstream	Irrigation	Public	Downstream	Irrigation
Total period Delivery (Mm3)	356.8	7165.6	22366.2	357.2	7179.8	22376.3
Total period deficit (Mm3)	0.36	14.21	236.81	0.00	0.00	226.7
Total duration of failures, *fd*	1	1	11	0	0	11
Number of failure sequence, *fs*	1	1	1	0	0	1
Time-based reliability, *Rt*	99.74	99.74	97.14	100.00	100.00	97.14
Volume-based reliability, *Rv*	99.90	99.80	98.95	100.00	100.00	99.00
Resilience, φ	1.00	1.00	0.09	-	-	0.09
Vulnerability, η	1.000	1.000	0.330	0.000	0.000	0.305
Sustainability, λ	0.000	0.000	0.390	1.000	1.000	0.395
Group sustainability, λG	0.292			0.546		

derived rule

Summary

- The standard genetic algorithm (SGA) has been improved by search space modification using DGA in which boundaries are continuously updated by modified search space reduction technique (SSRT).

- The search space is focused around the area of the optimal solution, hence speeding up the convergence process and improving the precision of solutions.

- Recorded computational times for the DGA were on average about half of those required by a standard algorithm solving the same problem

- Sustainability indices showed that the DGA was better than the SGA, for the individual water supply categories as well as their aggregation.

@hw.ac.uk