# Assessing the impact of land management changes on nutrient loads with the Reliability Ensemble Averaging (REA) method

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## 1. Scenario analysis in hydro-biogeochemical modelling

Classical approach:

Calibration and prediction by a single model

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Alteration of relevant boundary conditions

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Re-run and study of difference between original and new prediction

But …

… how reliable is an extensively calibrated model under changed boundary conditions?

… would a multi-model ensemble predict the same changes?

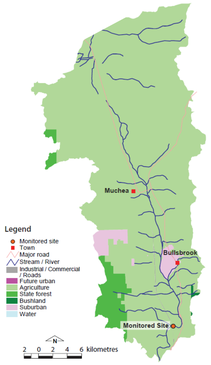
## 2. Ensemble modelling

- Pools different predictions of the same system
- Aims at balancing strengths and weaknesses between members
- Widely used in climate sciences
- Averaging methods usually provide more reliable predictions than single models
- State-of-the-art method to circumnavigate structural uncertainty issues

## 3. Ellen Brook River

- Located in south-west Western Australia
- Mediterranean climate with cool and wet winters, dry and hot summers
- Contributes 6% and 10% to total annual stream flow and N loads entering the Swan Canning estuary
- High frequency N monitoring
- Inorganic N represents about 10% of TN

Monitoring station




Catchment delineation

Due to frequent algal disturbances, the Swan River Trust [1] set a reduction of N loads by 50% over next years.

## 3. REA method

Philosophy [2]:

Model reliability under current conditions

Convergence with other ensemble members

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Model weights in the averaging scheme

Put in a mathematical way, each model *i* of the ensemble is assigned a weight *w* computed such as

$$w_i = \left(R_i^m \cdot C_i^n\right)^{1/(m \times n)}$$

where $R_i$ and $C_i$ are the reliability and convergence criteria of model *i*, respectively. Coefficients *m* and *n* are used to give more importance to either the reliability or the convergence criterion.

## 4. Ensemble setup

- Four model structures: LASCAM, CHIMP, SWAT and HBV-N-D
- Calibration to simulate daily runoff and TN fluxes between 01/01/1989 and 31/12/1997
- Scenarios of reduction in N fertiliser application set between 01/01/1998 and 31/12/2006
- REA using the inverse of the RMSE during calibration as reliability criterion and the inverse of the absolute difference between model as convergence criterion.

## 5. Calibration results

| Model | RMSE [ g N / (ha d)] | | TN export [t N/ yr] | |
|---|---|---|---|---|
| | Calibration | Validation | Calibration | Validation |
| LASCAM | 5.4 | 7.1 | 83.0 | 59.7 |
| CHIMP | 10.8 | 9.9 | 84.9 | 69.0 |
| SWAT | 18.4 | 26.2 | 131.1 | 117.7 |
| HBV-N-D | 14.3 | 10.4 | 34.3 | 31.3 |

## 6.Scenario results and discussion

Results of the different scenarios for the different models and some averaging techniques are summarised in Figure 3.

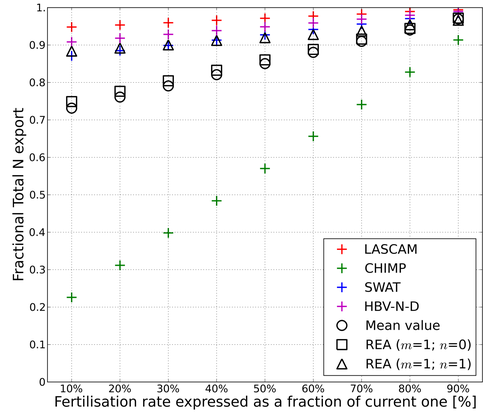


**Fig. 3** Scenario results for single models and ensembles

Although they predict very different absolute TN fluxes predictions, all models except CHIMP have a similar absolute response to the same scenario. If we only use a simple average or a weighted mean based on calibration results (*n*=0), the outlying position and calibration performances of CHIMP (2nd best) pull the ensemble towards higher response to fertilisation rate reduction. By integrating the convergence criterion (*n*=1), the REA provides a more reliable scenario result without totally disqualifying any of the models.

This method has a great potential in the hydro-biogeochemical modelling context.

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**References**

[1] Swan River Trust 2009, *Swan Canning Water Quality Improvement Plan*, Perth, WA, Australia

[2] Giorgi and Mearns 2002, J Clim., 15: 1141-1158