The 18th AIM international Workshop

Climate change impact on the TN generation of Lake Rotokakahi catchment, New Zealand

Wei Ye[1]
Wang Yao[2]
David Hamilton[1]
[1]University of Waikato, New Zealand
[2]Hohai University, China

Background

- The quality of most New Zealand lakes has been threatened by the dramatic land use change in their lake catchment;
- The hydrological process is the main driving force in transporting the land based pollutant to become pollutant load in a lake;
- Climate change will have add-on effects on this dynamic process due to its impact on regional hydrology;
- This research presents the climate change impact on extreme rainfall and subsequently its effects on lake catchment TN generation.

Method

- Integration of hydrological model and climate change impact assessment model

Hydrological model selection:

- Including required information as input;
- Including required information as output;
- Applying for ungagged catchment modeling.

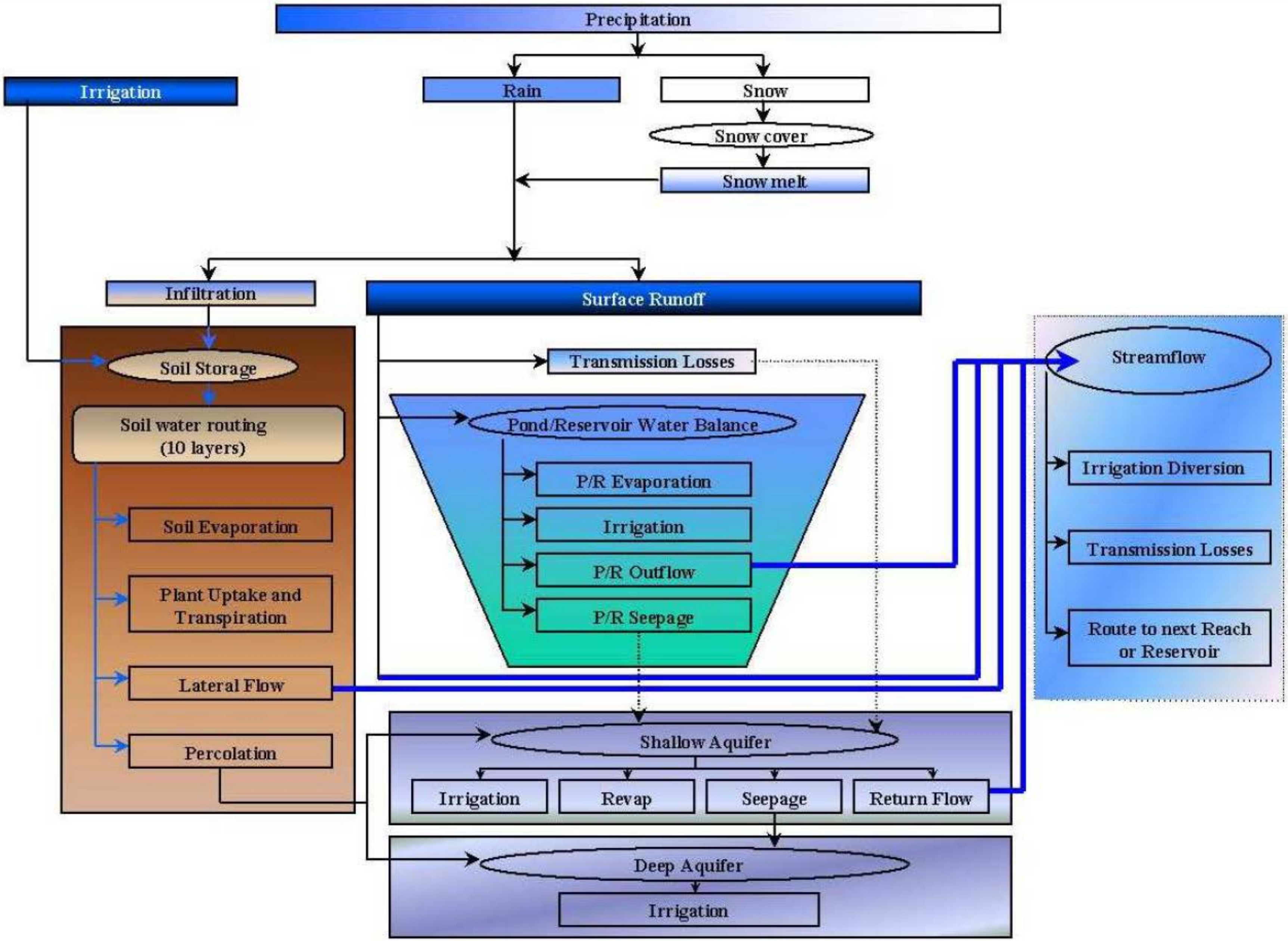
Climate change impact assessment model selection:

- Efficient scenario generation for multiple model ensemble
- Including all uncertainty sources in climate change scenarios.

Method

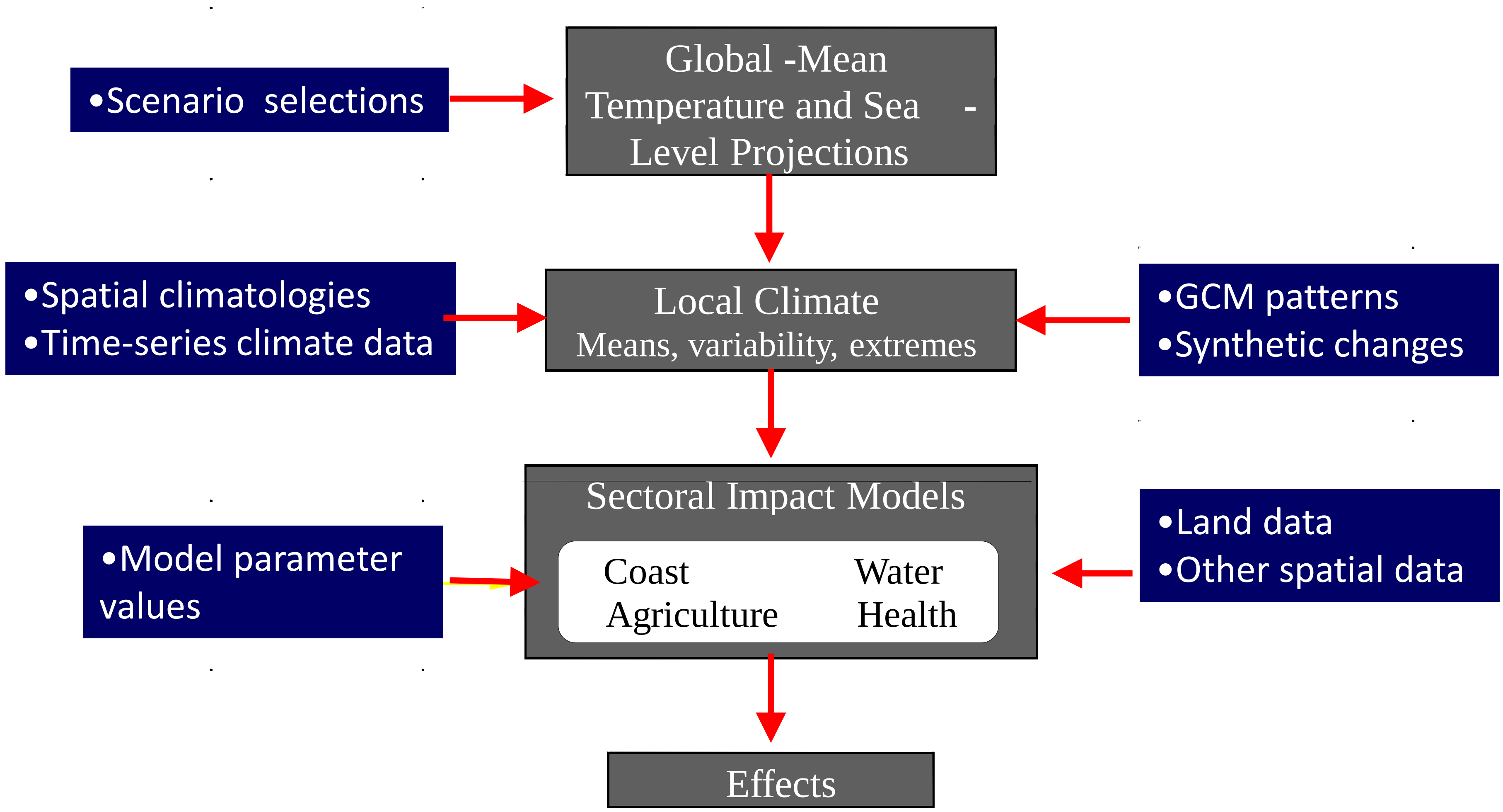
- Hydrological model: SWAT - Soil and Water Assessment Tool
  - Process based distributed model;
  - Besides climate factors, also includes detailed land and soil information that affect the hydrological process;
  - Including all required major hydrological/bio-chemical as outputs
  - Can be used for ungagged catchment modelling.

- Climate change scenario model: CLIMPACTS
  - A pattern scaling based GCM (RCM) model ensemble method of climate scenario generation;
  - Including the uncertainty sources of GHG emission; climate sensitivity; as well as uncertainties among GCMs (RCMs);
  - Including extreme event change scenario generation.

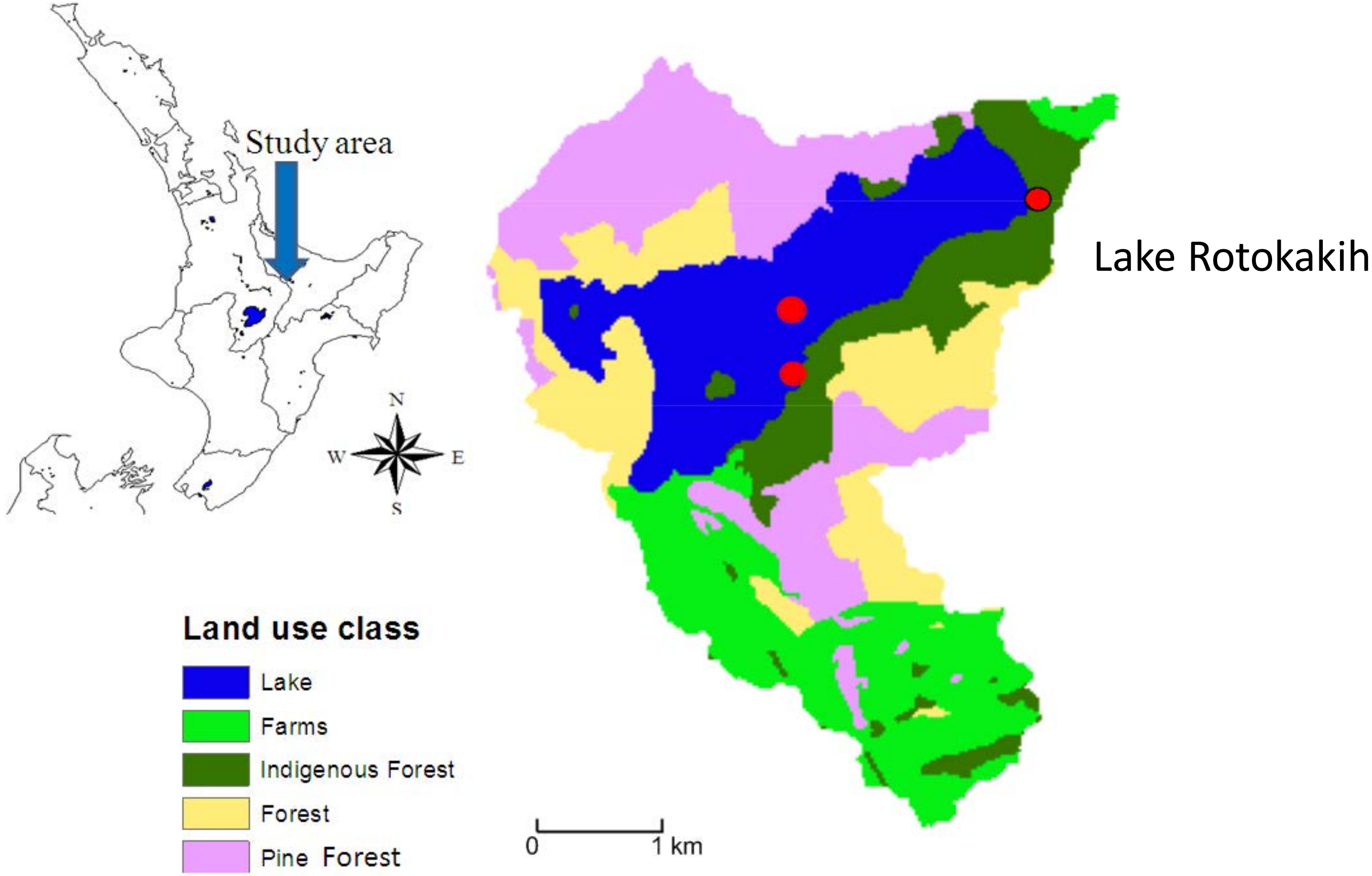


Schematic of pathways for available water movement in SWAT (Neitsch et al., 2005)

CLIMPACTS Model Structure



Case study area



The water surface area of the lake is 4.6 km^2. The mean depth is just 17.5 metres. The Lake catchment has a total land area 15 km^2

SWAT model Set-up

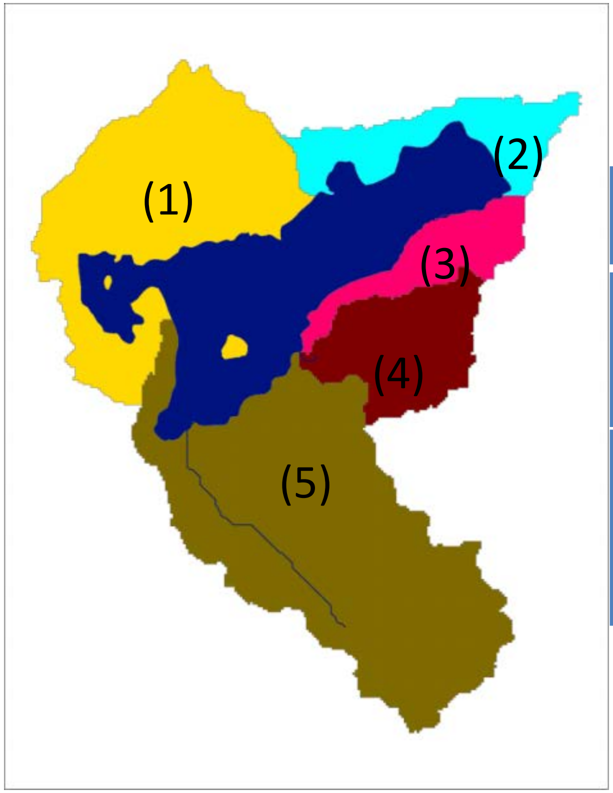
Lake Rotokakihi:

- Ungagged catchment;
- Small in size and mostly fed by surface flow and lateral flow
- Minimum human interference

Model parameterization:

- Calibration and validation was carried in a nearby catchment about 8 km away, with the same meteorological station data;
- Two catchments are characterised by similar geographic and land use features;
- Five most sensitive parameters was adopted from the nearby catchment validation;
- Soil attributes are obtained or estimated from observation;
- SWAT default settings were used for other model parameters

SWAT model Result

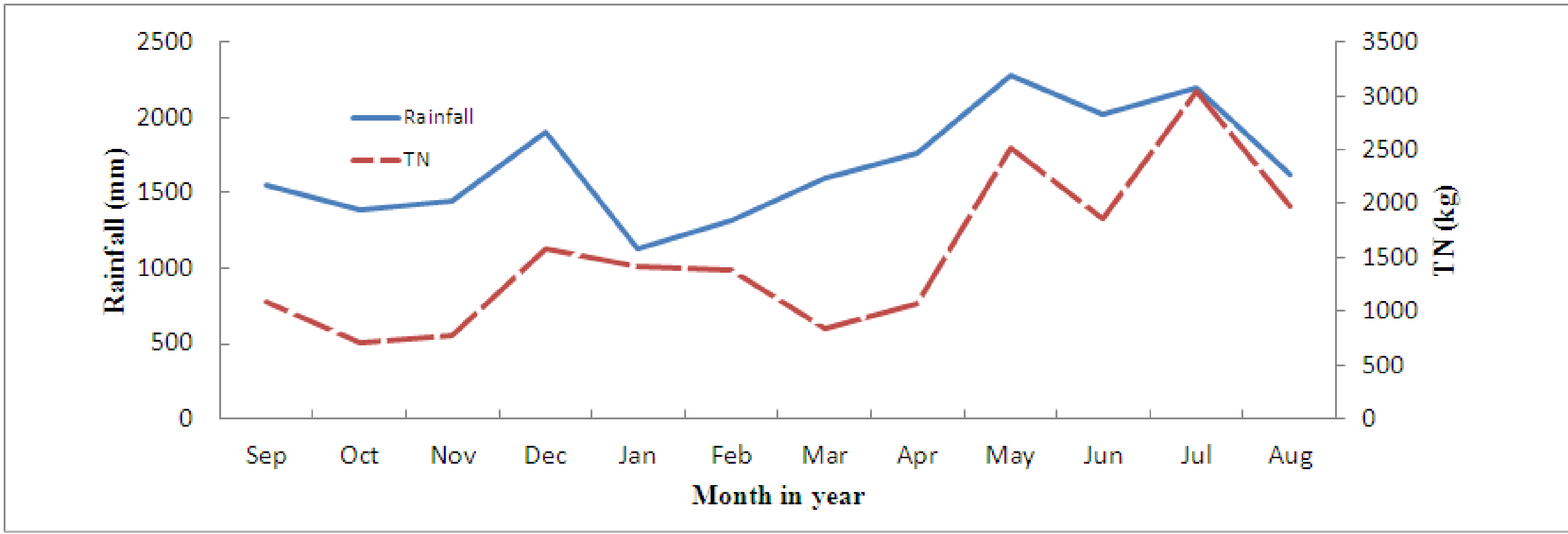


SWAT model sub-catchment delineation for Lake Rotokakahi (25x25 m DEM)

SWAT simulated annual average TN load for each sub-catchment.

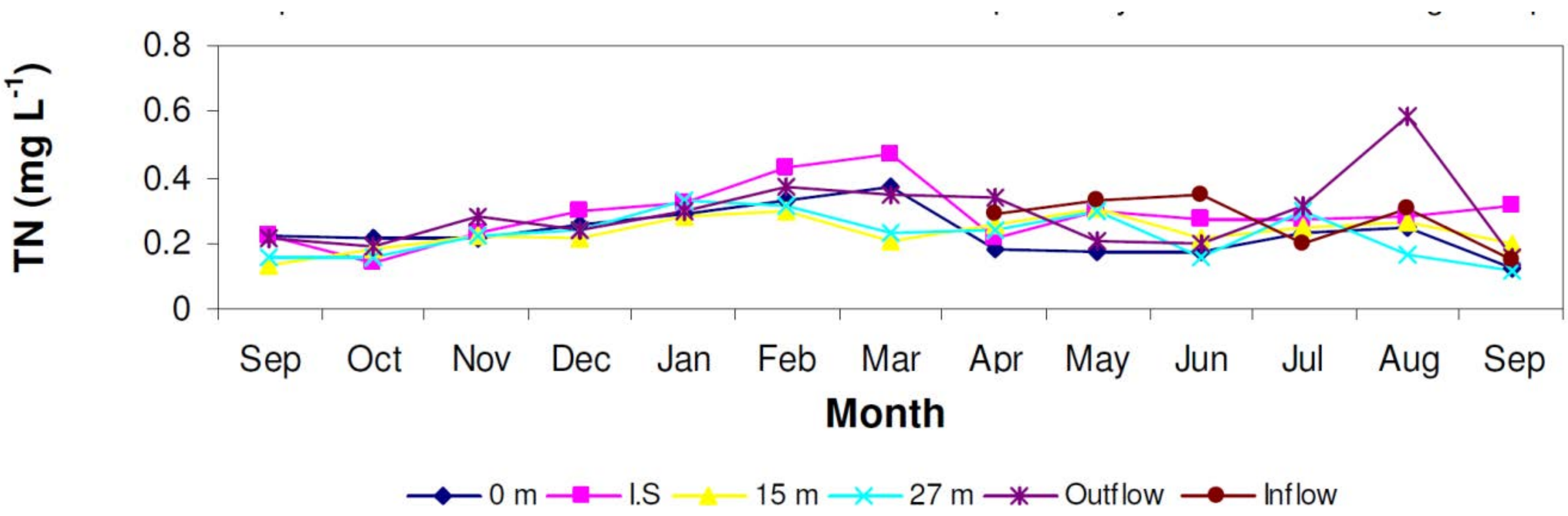
Sub-catchment	1	2	3	4	5
Area (ha)	386	140	129	162	670
Simulated annual average TN load (kg/ha/Year)	8.90	11.67	8.90	7.94	16.10

SWAT model Result



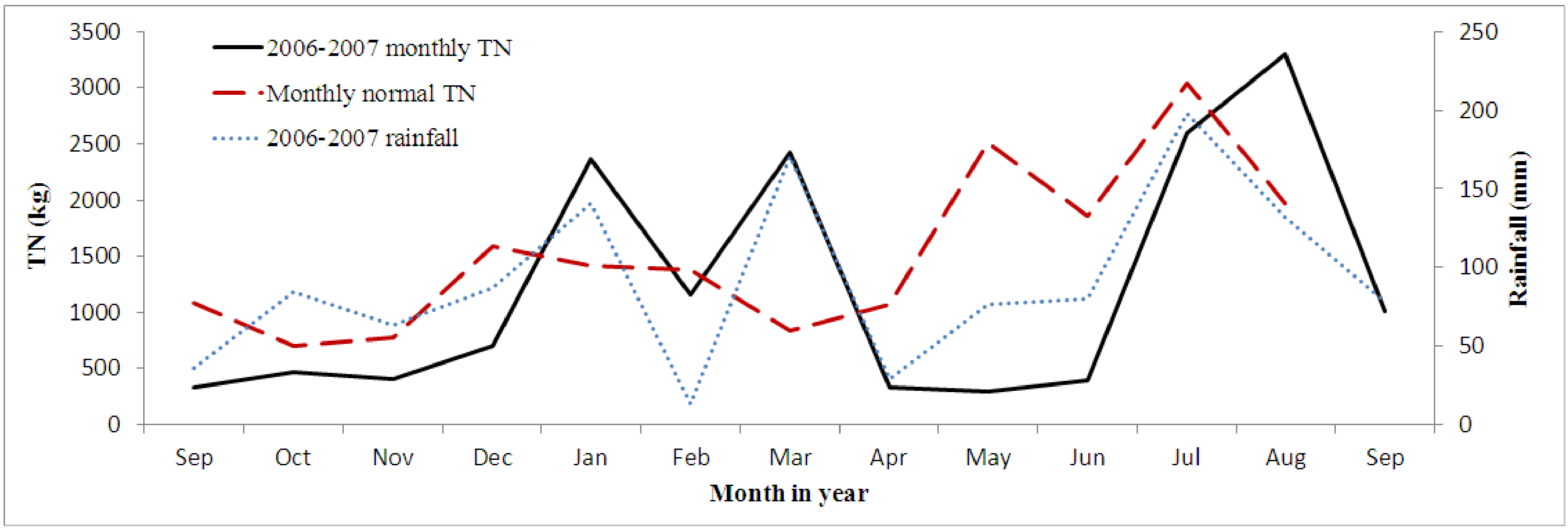
Observed monthly normal rainfall and SWAT simulated monthly normal TN for the period of 1993 to 2007

SWAT Model Validation

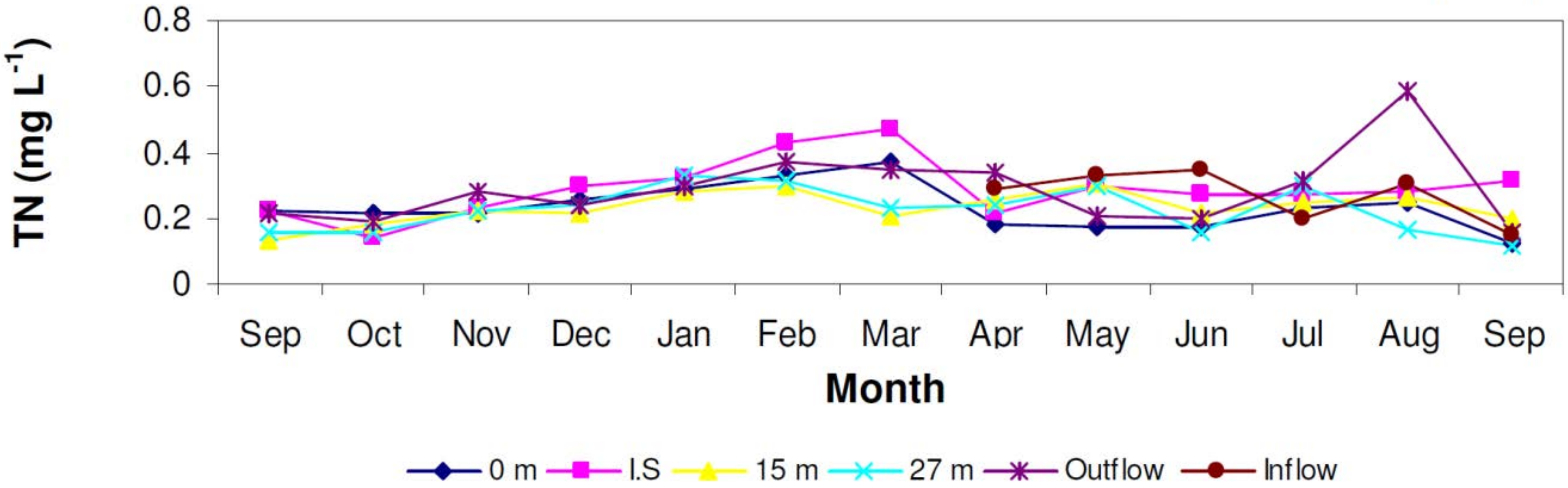


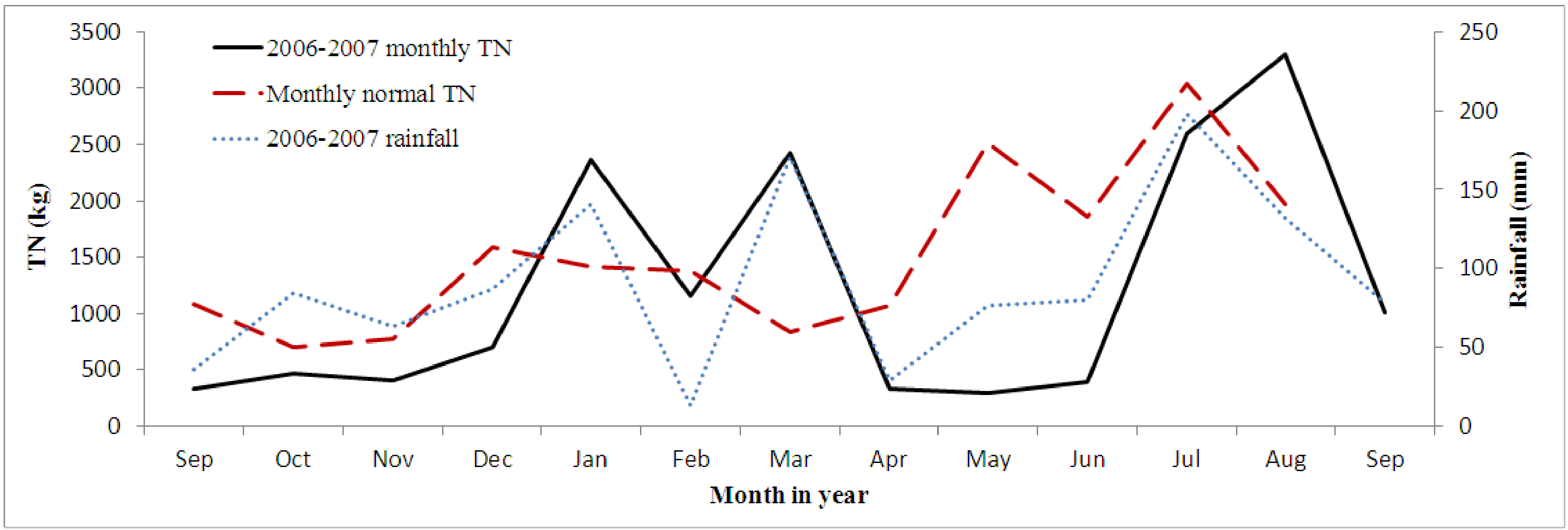
Observed Lake Rotokakahi TN over 2006 to 2007 (from Butterworth, 2008)

SWAT Model Validation

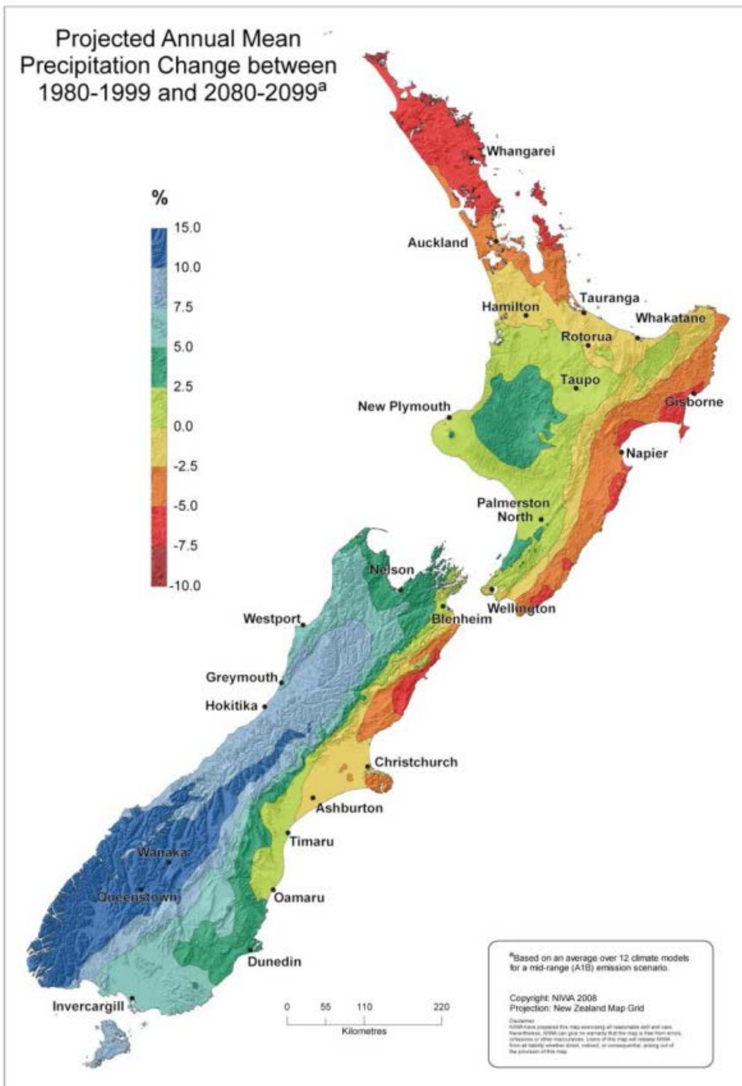


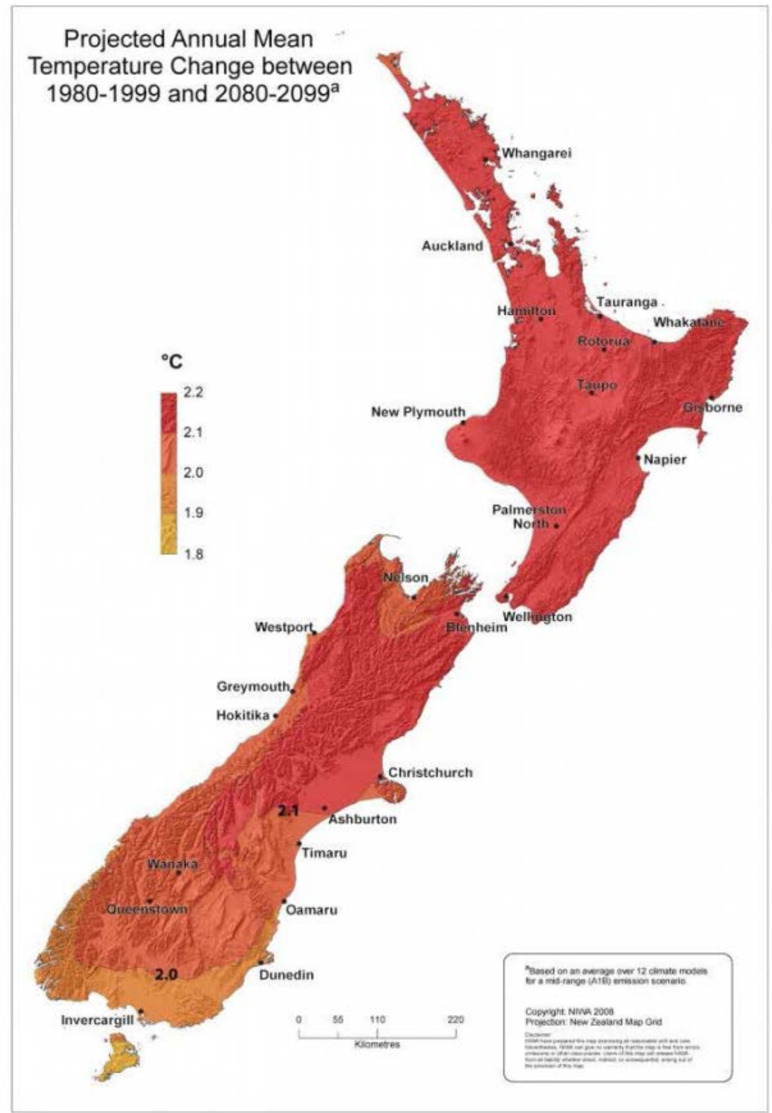
SWAT simulated monthly TN for Lake Rotokakahi catchment over 2006 to 2007


TN (mg L^{-1})
0.8
0.6
0.4
0.2
0
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
0 m
I.S
15 m
27 m
Outflow
Inflow

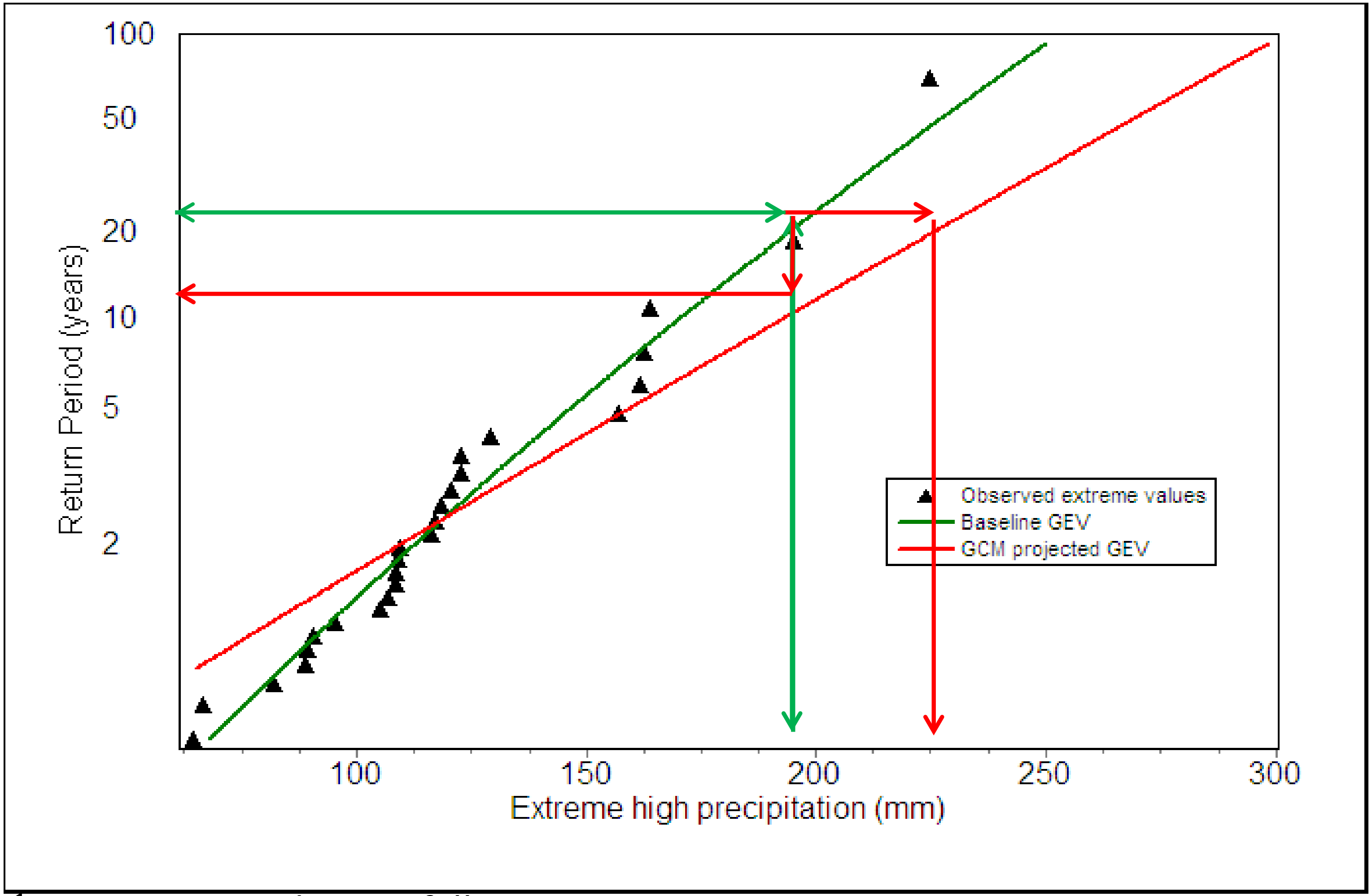

TN (kg)
3500
3000
2500
2000
1500
1000
500
0
2006-2007 monthly TN
Monthly normal TN
2006-2007 rainfall
250
200
150
100
50
0
Rainfall (mm)
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month in year

Climate Change Scenario





Climate Change Scenario



[1]Consecutive 2 day rainfall

[2]Projection based the median value of 12 GCM ensemble with IPCC SRES A1B emission scenario and Mid Climate Sensitivity for the future year of 2100

Impact Assessment

SWAT 2 day annual maximum rainfall event results for the simulation period

Date	Annual Maximum 2 day rainfall (mm)	Return period (years)		Annual total rainfall (mm)	Event to annual ratio (%)
		Baseline	2100 projection		
1-2 May 1999	225	68	24	1397	16%
23-24 Dec. 1995	163	9	5.5	1823	9%
25-26 Jan. 2006	162	9	5.5	1469	11%
17-18 Jul. 2004	157	7.5	5	1504	10%

Impact Assessment

SWAT simulated TN corresponding to the extreme rainfall events during the simulation period

Date	TN caused by extreme rainfall event for each sub-catchment (kg/ha)					Event total (kg)	Annual total (kg)	Event to annual ratio (%)
	1	2	3	4	5			
1-2 May 1999	3.01	3.11	2.99	3.18	6.64	6946	20431	34%
23-24 Dec. 1995	0.95	1.35	0.95	1.07	2.43	2440	18992	13%
25-26 Jan. 2006	1.77	2.36	1.77	2.38	3.07	3685	24693	15%
17-18 Jul. 2004	3.77	4.03	3.77	4.07	8.57	8905	29049	31%

Impact Assessment

- The total rainfall over the simulation period is 20229 mm and the TN load simulated for the whole period is 273668 kg, which indicates a long term average TN per unit rainfall generation of 13.5 kg/mm
- The TN from these four events is account for about 8% of the TN simulated for the whole period. The TN per unit rainfall generation of these four extreme events is 31 kg/mm,

Impact Assessment

$$\Delta TN = \frac{1}{N}\sum_{i=1}^{n}\left[TN_i\left(ARI_i^b\right) \times \left(\frac{ARI_i^b}{ARI_i^f} - 1\right) - \overline{TN} \times P_i^b \times \left(\frac{ARI_i^b}{ARI_i^f} - 1\right)\right]$$

ΔTN is annual average increase of TN due to climate change impact on extreme rainfall event;
N is the number of simulation years; *n* is number of extreme rainfall events in the simulation period;
ARI_i^b is the baseline annual return year of the i^{th} extreme event;
ARI_i^f is the annual return year of the i^{th} extreme event in the future year *f*;
TN_i (API_i^b) is the TN load generated by the extreme event of *i*;
P_i^b is the total rainfall of the i^{th} extreme event.

$\overline{TN}$ is the long term average TN load produced by rainfall: $\overline{TN} = \frac{\sum_{y=1}^{N} TN(y)}{\sum_{y=1}^{N} P(y)}$

y is the simulation year; *TN*(*y*) is the TN generated in year *y*; and
P(*y*) is the total annual rainfall of year *y*.

Conclusion

- Based on a middle range climate change scenario, the Lake Rotokakihi catchment annual TN load generation will likely increase by 4% by 2100 from present;
- The middle range climate change scenario is based on a business as usual GHG emission scenario (SRES A1B) and a median value of extreme rainfall projection from 12 GCM model ensemble;
- Given the pastoral farming as the biggest land based TN contributor, it is critical to optimise farmland management or converse some of pastoral land to forest in order to maintain and restore the water quality for Lake Rotokakihi.

Limitation and Future Work

- Limited observation data
  - For model calibration and validation
  - For establish reliable statistical relationship between extreme rainfall and TN generation
- Transient scenario simulation
- Integration of a dynamic lake model for lake quality modelling