Modelling nitrogen in streamflow from boreal forest watersheds in Alberta, Canada, using SWAT

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Scope of the Study

To explore the feasibility of using SWAT as a nitrogen export modelling tool in forest dominated watersheds on the Canadian Boreal Plain.

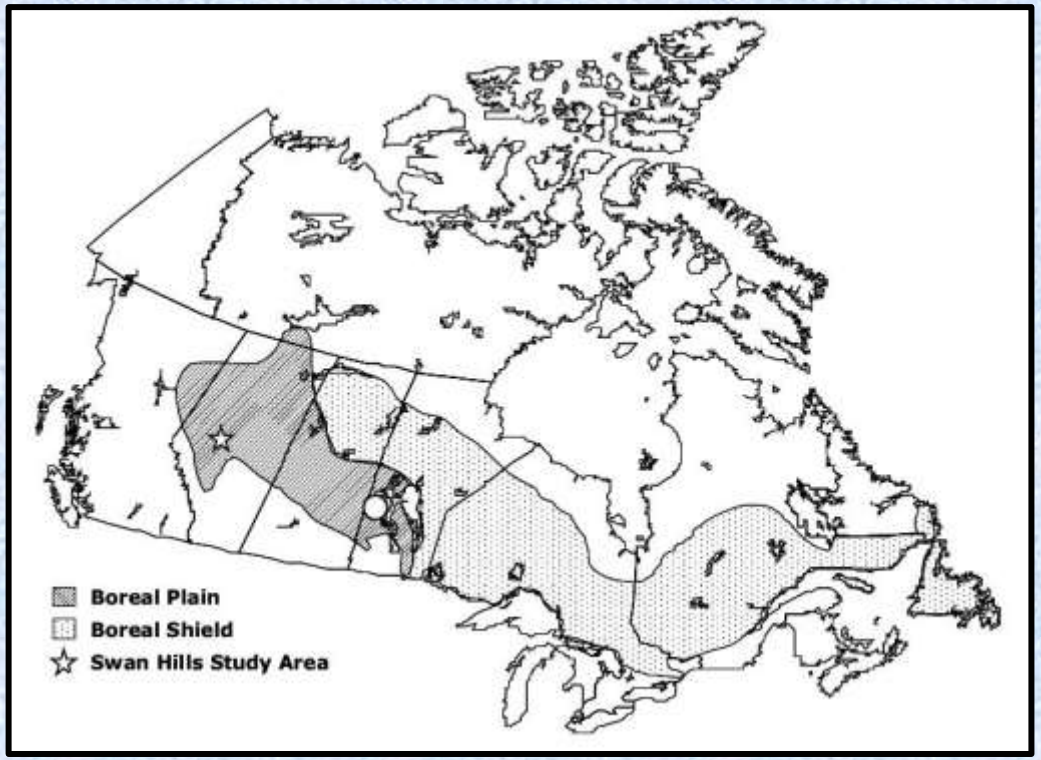
•Boreal forests comprise ~ 35 % of the land surface area and ~ 77% of forested land in Canada (Smith et al. 2003).

• Forest harvesting have increased in last 3 decades (from 6.5 to 23.3 million m^3 between 1984 and 2002 (Alberta Economic Development 2003).

• Harvesting of boreal forest affects nutrient status, hydrological processes and stream water yield and quality.

• No effective management tool till recent years

• FORWARD (Forest Watershed and Riparian Disturbance) launched : aim to integrate ecosystem processes with watershed management practices.



One of the goals of FORWARD :

Development of a range of hydrological and ecological models to predict the impacts of natural and anthropogenic disturbances on streamflow quantity and quality.

For hydrological purposes :

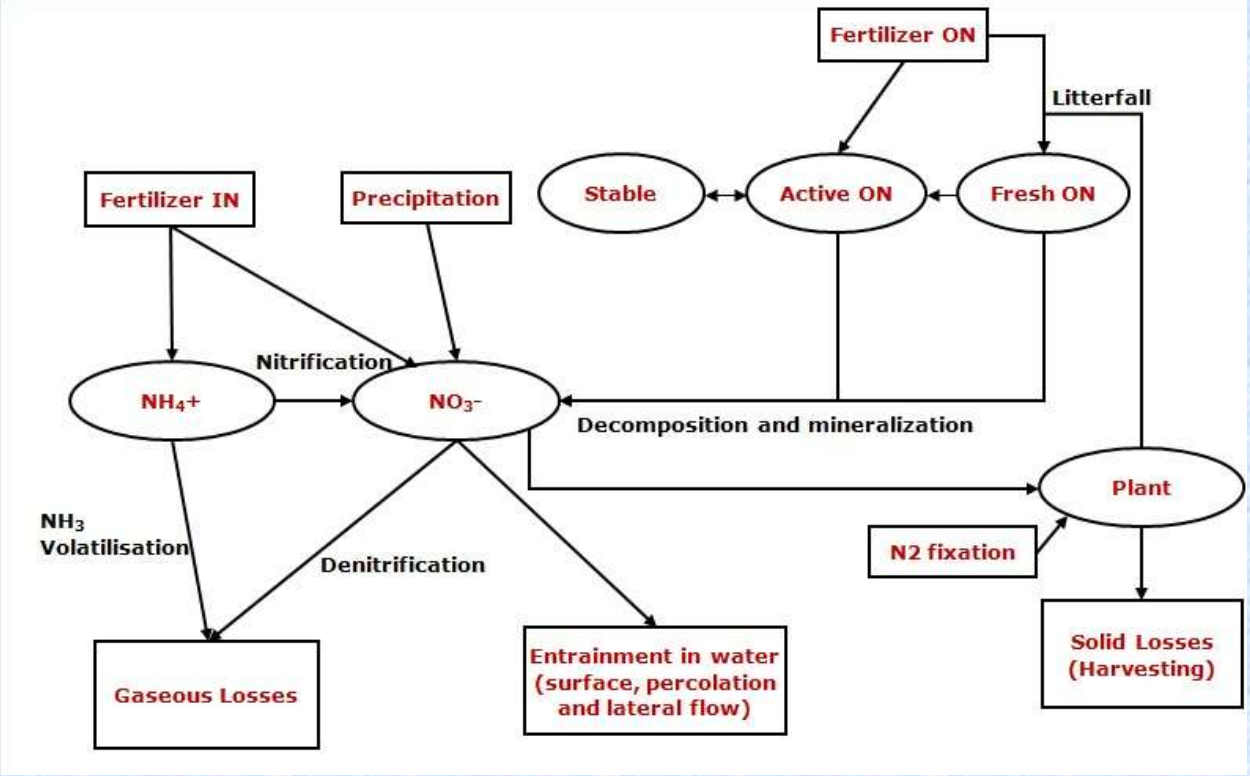
*** Different models were considered and SWAT was found to be the most suitable one (Putz et al. 2003).**

*** Later modified to include hydrological processes more relevant to forest ecosystems (Watson et al. 2008).**

Now being studied for water quality : mostly N export

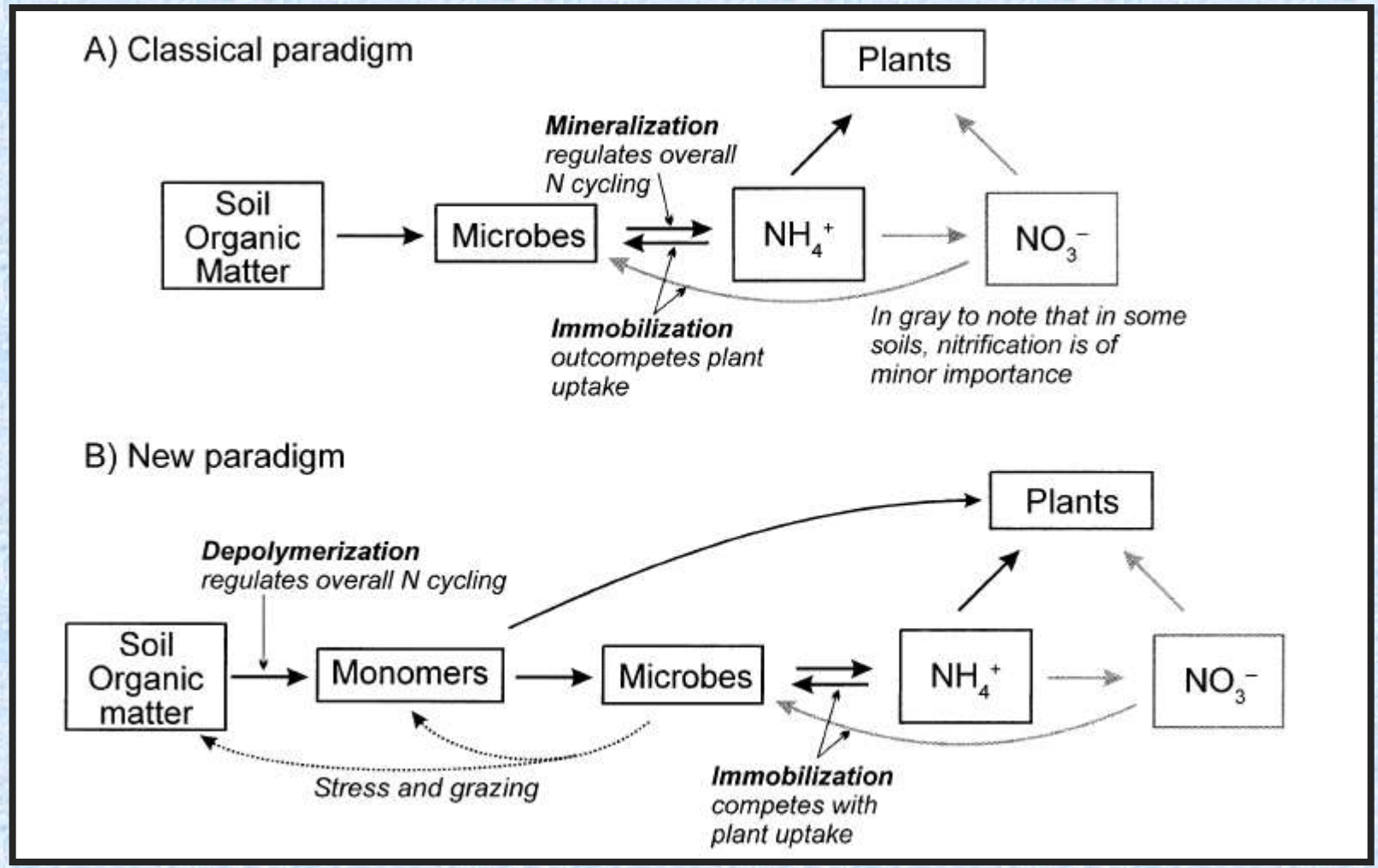
Basic Framework of SWAT

- A net mineralization model as organic N is directly converted to nitrate without taking intermediate ammonium into account.
- Plants can only take up N in form of nitrate, which may not be correct.
- Only source for ammonium is fertilizer.
- Gaseous N losses are not modelled perfectly.



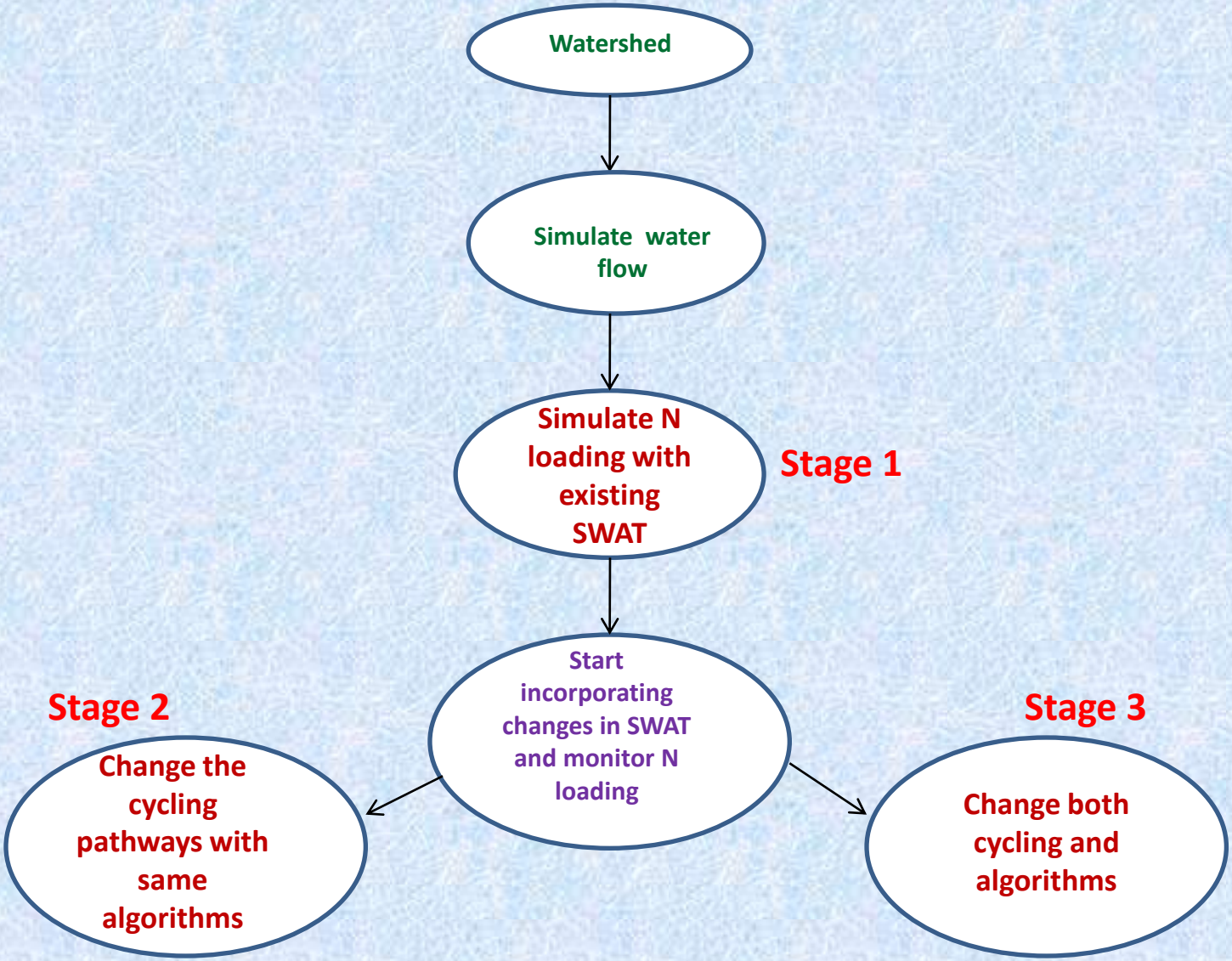
SWAT NEEDS MODIFICATION FOR N SIMULATION IN FORWARD SITES

Paradigm of Soil N cycle



Schimel and Bennett 2004

Our Strategy

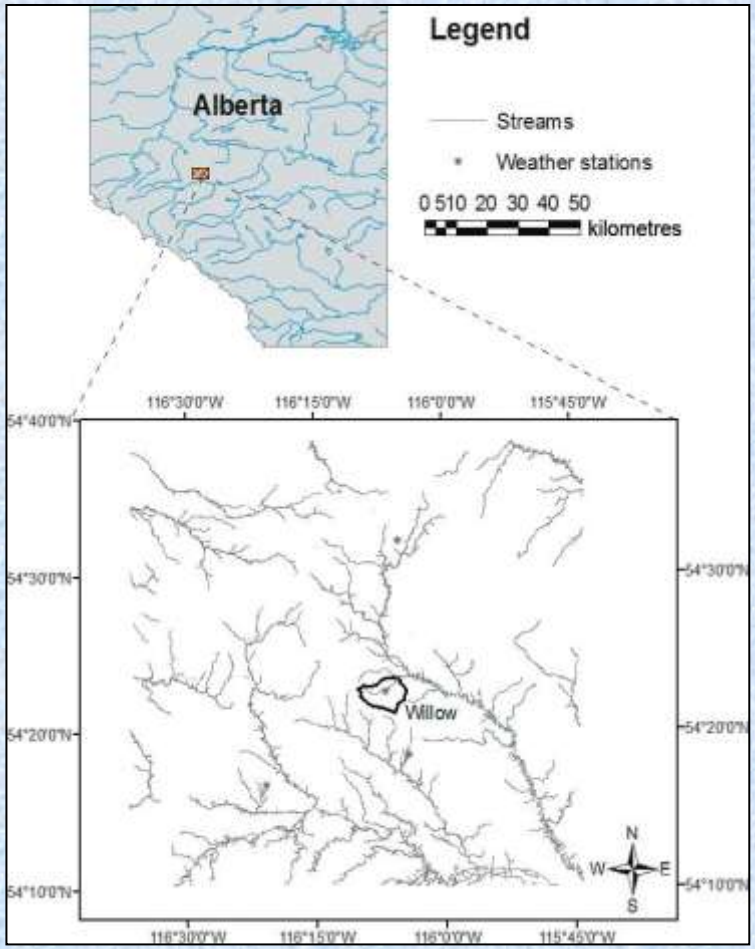


Stage 1

Simulate N loading with original SWAT

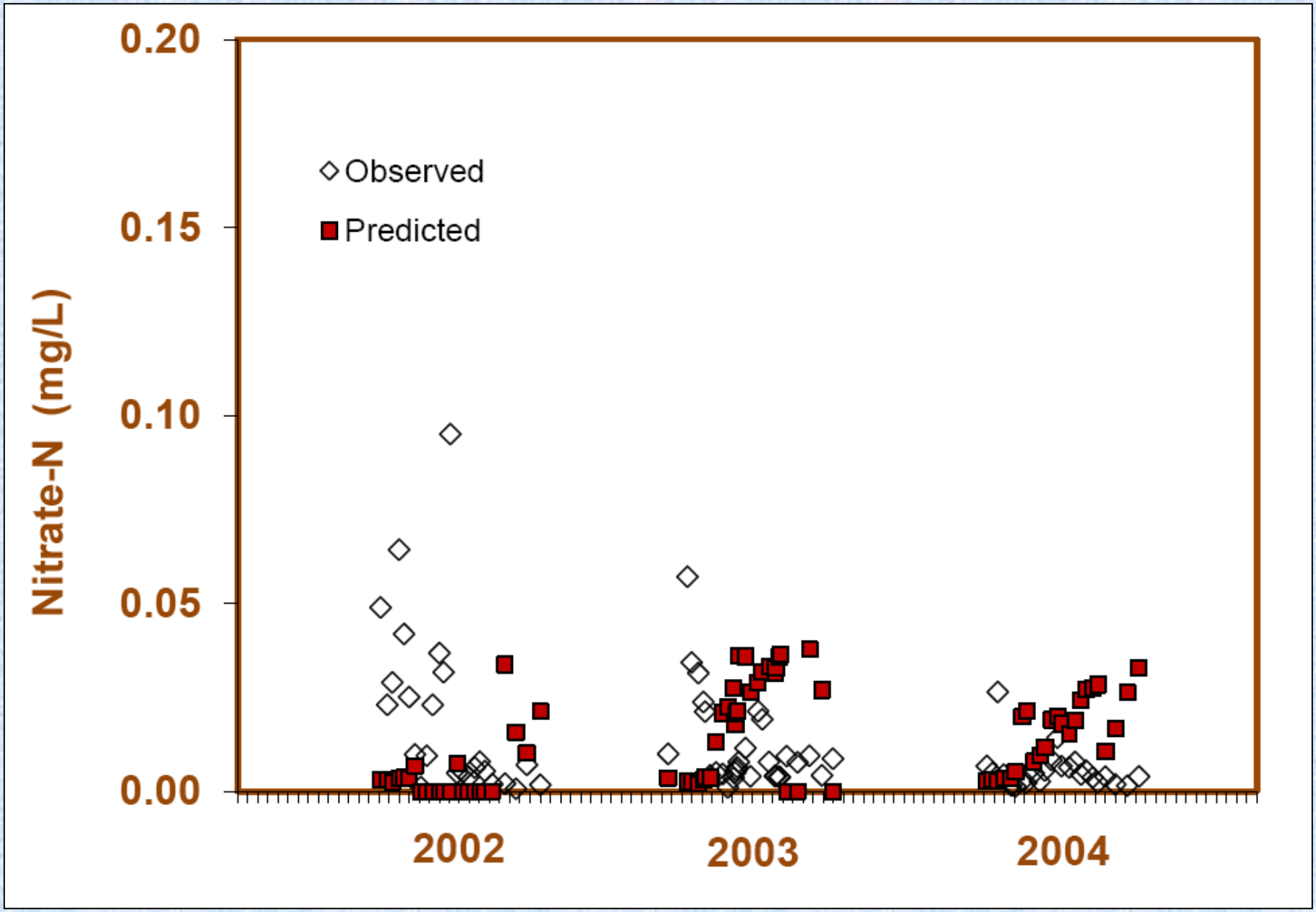
Willow Watershed

Area : (15.1 km^2)
Elevation : 870-1061 m
Hill slope : 0-13 %
Forest cover : 44 % mostly deciduous
24% mostly Coniferous
25 % mixed
Dominant Soil types: Luvisols, Organics and Brunisols



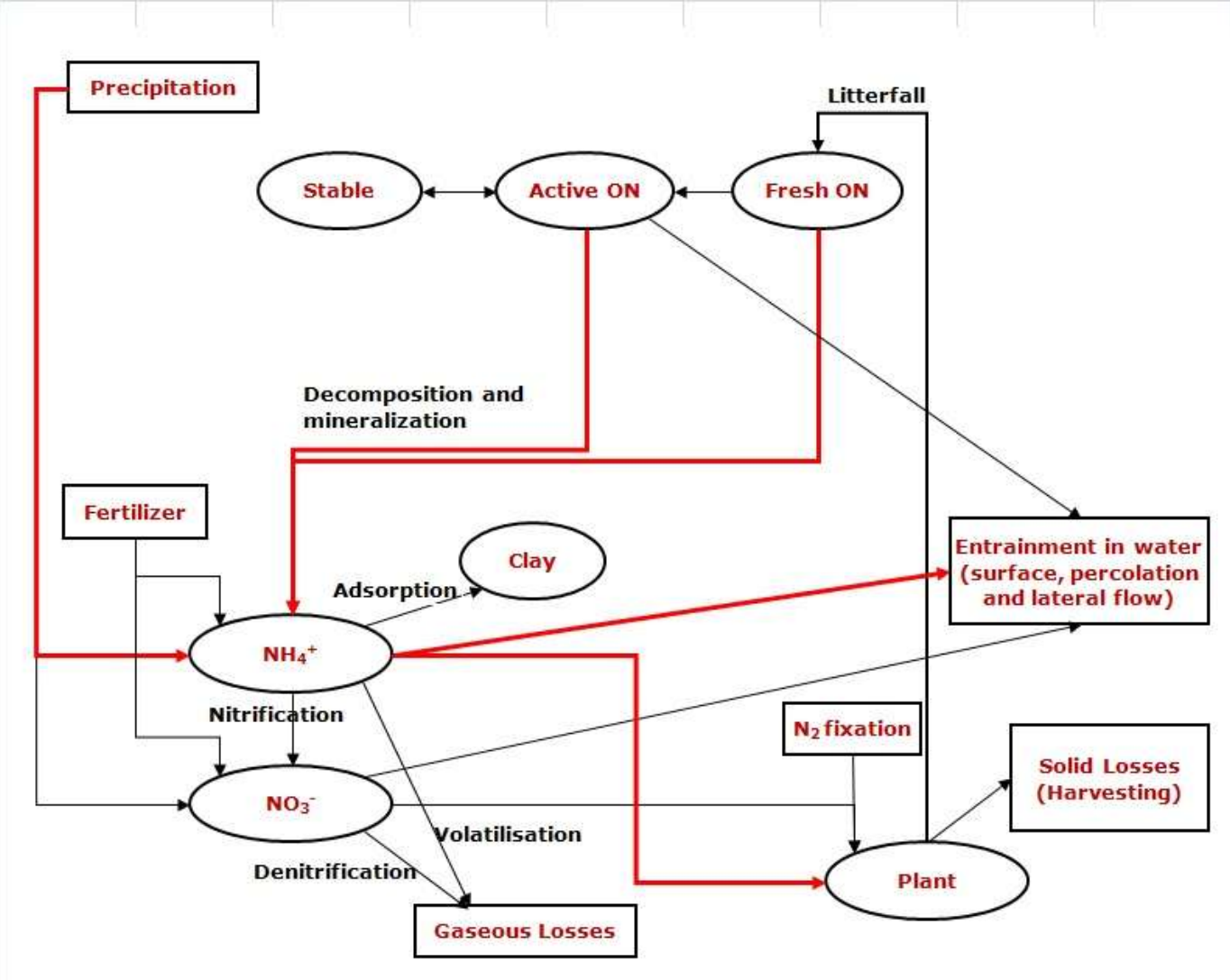
Calibrated Parameters:

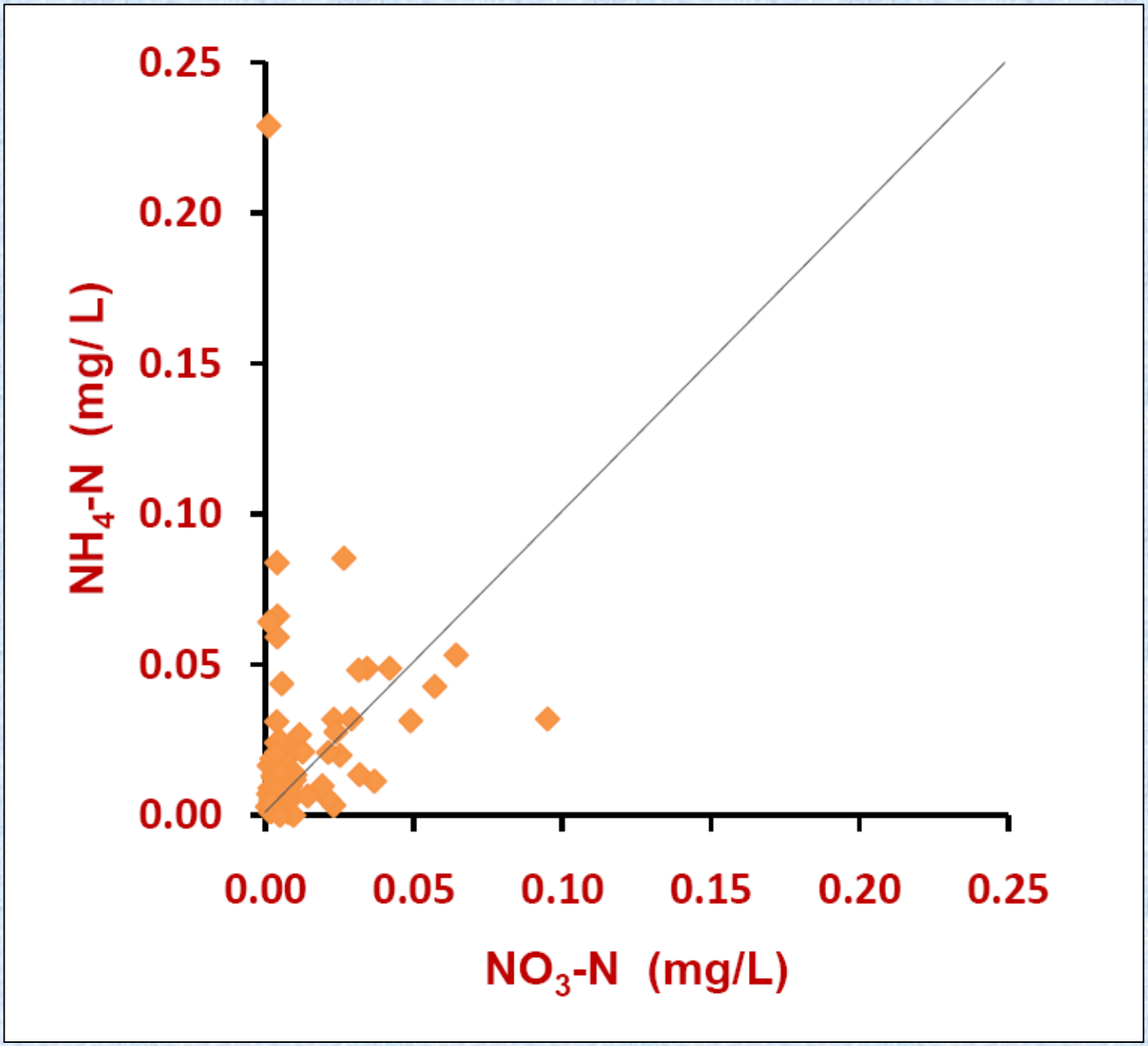
Variable	Description	Range	Values
CMN	Rate factor for humus mineralization of active organic N	0.0003-0.03	0.0003
N_UPDIS	Nitrogen uptake distribution parameter	1.00-20.00	13.58
NPERCO	Nitrate percolation coefficient	0.01-1.00	0.01
RSDCO	Residue decomposition coefficient	0.01-0.05	0.02
BIOMIX	Biological mixing efficiency	0-1.00	1.00


0.20
0.15
0.10
0.05
0.00
Nitrate-N (mg/L)
Observed
Predicted
2002
2003
2004

Stage 2

Modification Introduced in N cycling pathways

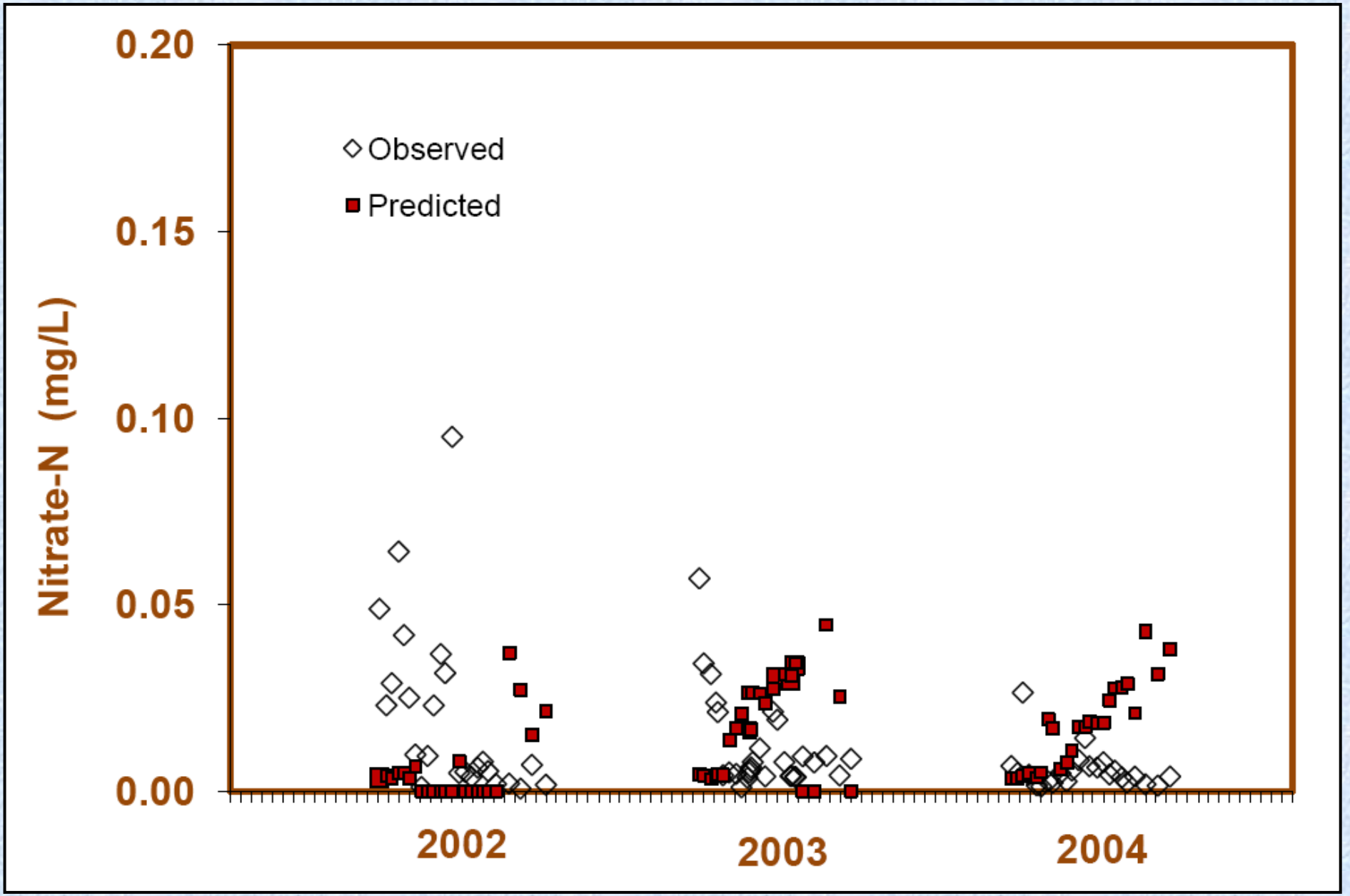



0.25
0.20
0.15
0.10
0.05
0.00
NH_4-N (mg/ L)
0.00
0.05
0.10
0.15
0.20
0.25
NO_3-N (mg/L)

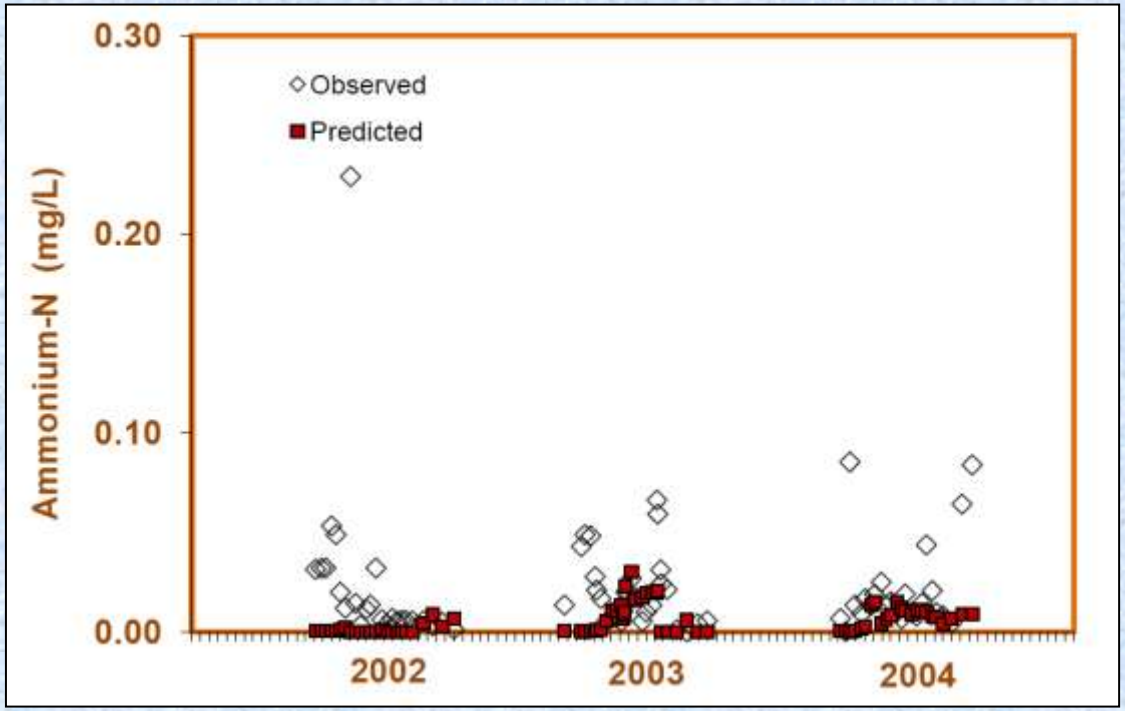
Calibrated Parameters:

Variable	Description	Range	Value		
			Nitrate		Ammonium
			Step 1	Step 2	Step 2
CMN	Rate factor for humus mineralization of active ON	0.0003-0.03	0.0003	0.0003	0.02
N_UPDIS	Nitrogen uptake distribution parameter	1.00-20.00	13.58	20.00	12.38
NPERCO	Nitrate percolation coefficient	0.01-1.00	0.01	0.01	0.47
RSDCO	Residue decomposition coefficient	0.01-0.05	0.02	0.03	0.03
BIOMIX	Biological mixing efficiency	0-1.00	1.00	0.71	1.00
NH4PERCO*	Ammonium percolation coefficient	0.01-1.00			0.01
NH4ADJ*	Ammonium adsorption factor	0.01-1.00			0.20

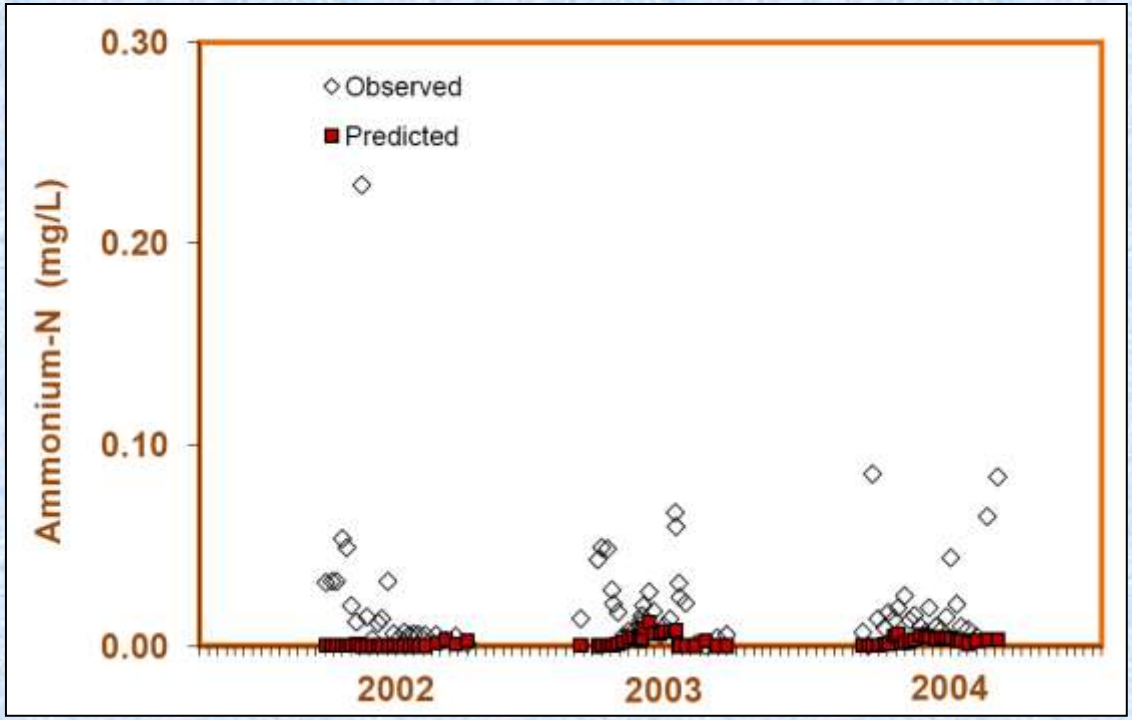
* Parameters calibrated only during Step 2


0.20
0.15
0.10
0.05
0.00
Nitrate-N (mg/L)
Observed
Predicted
2002
2003
2004

Adjustment factor ~ 0.2

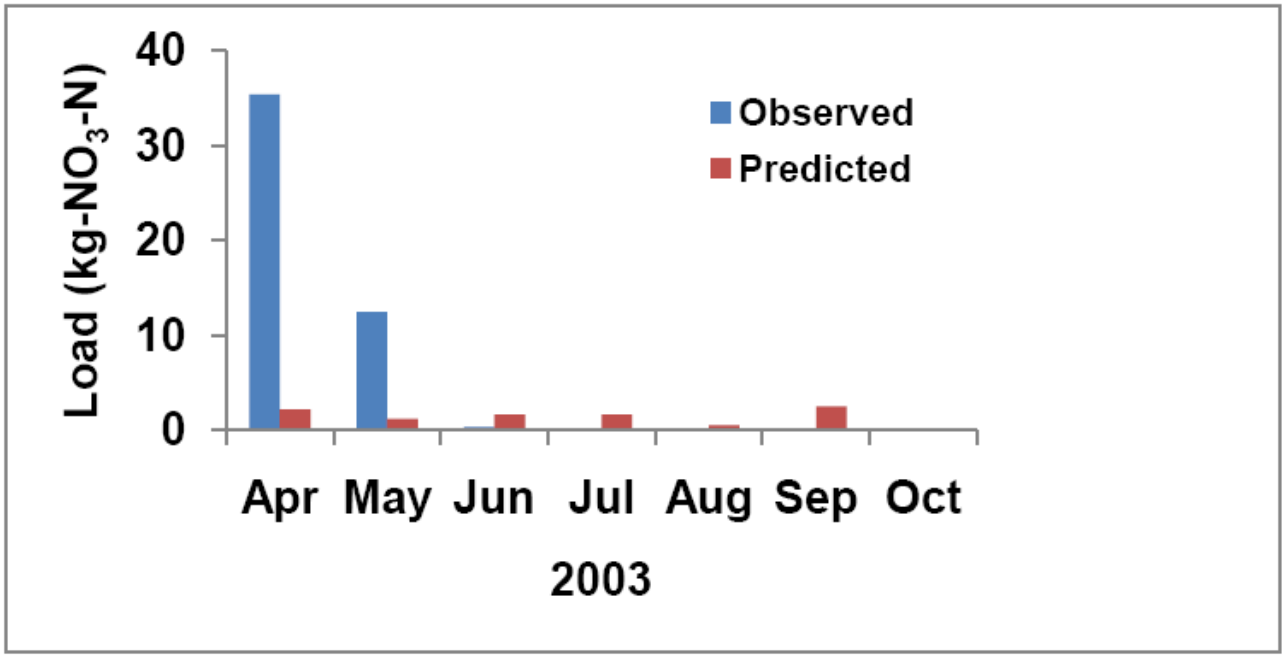


Adjustment factor ~ 0.7

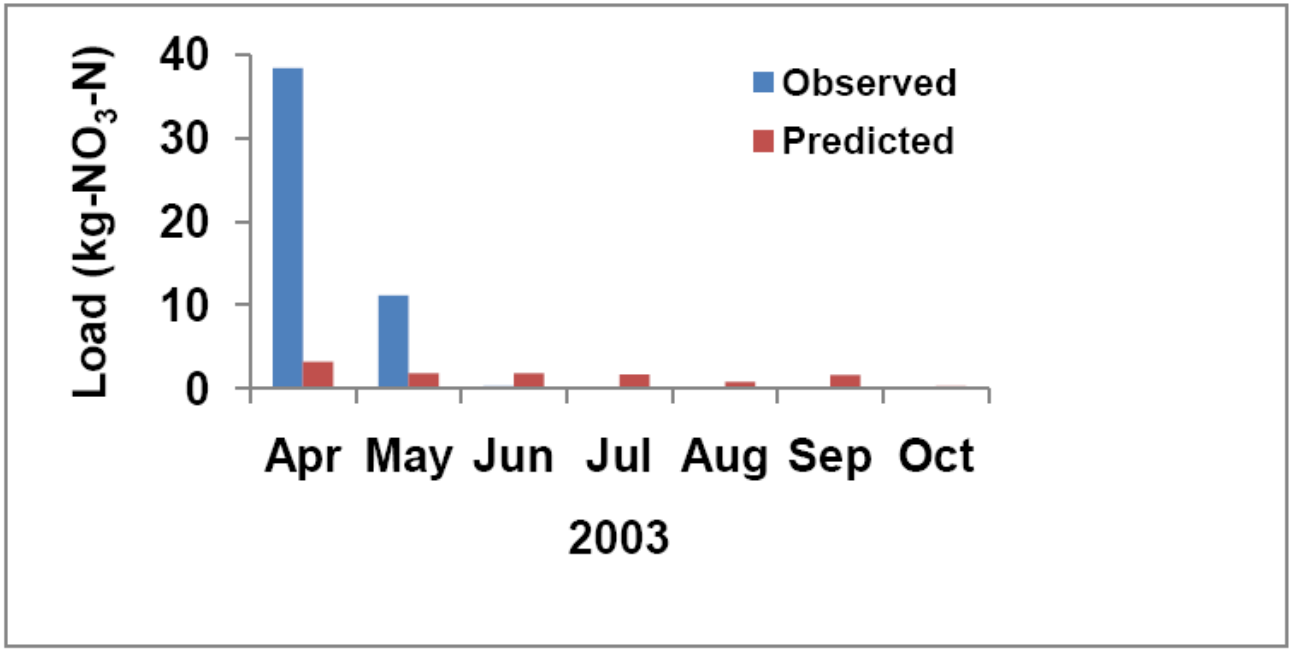


Monthly Loadings

Based on weighted method

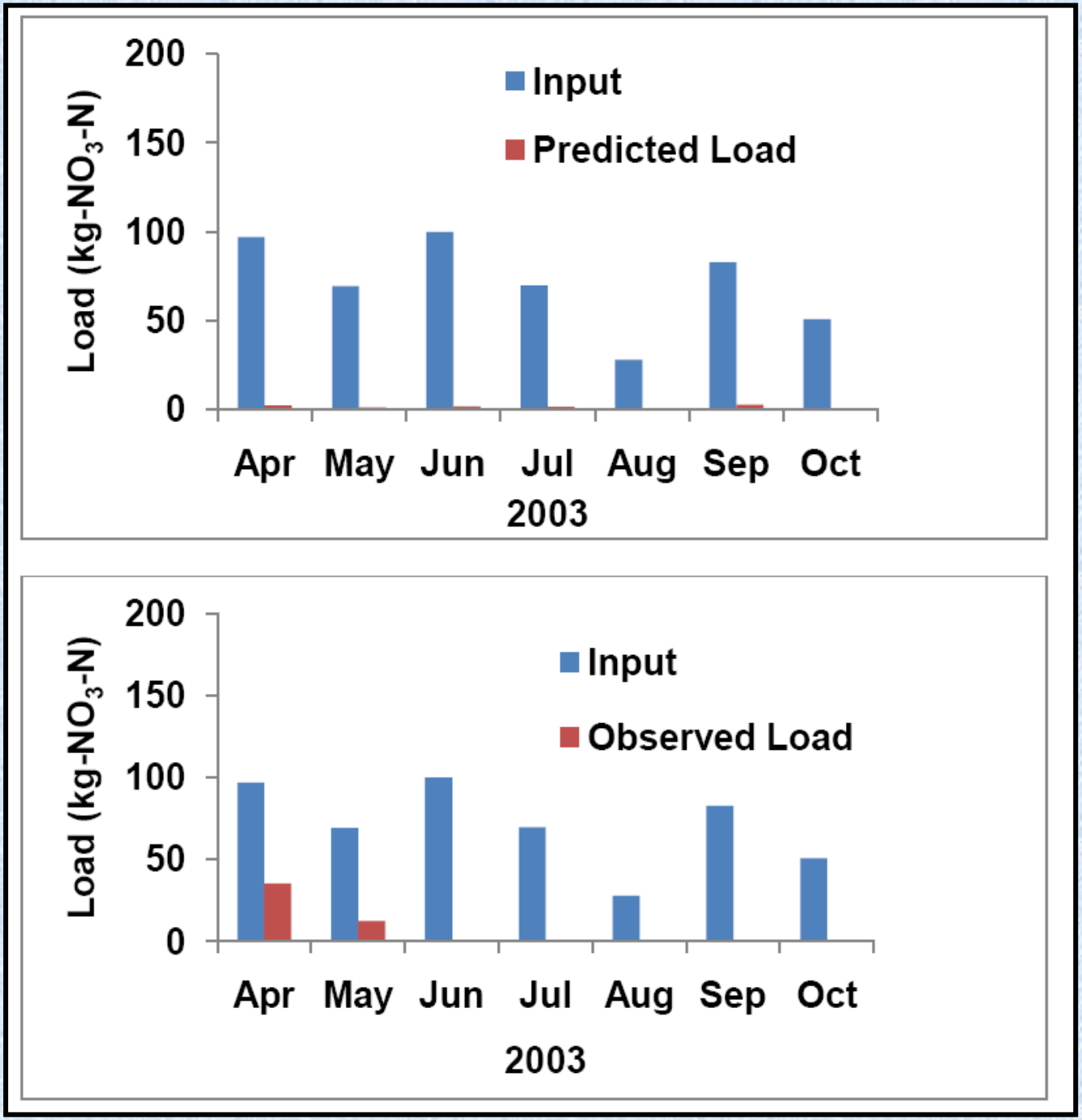


Based on average method



		Monthly load (kg NO_3-N)		
	Method 1		Method 2	
	Observed	Predicted	Observed	Predicted
Apr	35.40	2.15	38.42	3.24
May	12.44	1.19	11.15	1.87
June	0.33	1.63	0.33	1.85
July	0.14	1.61	0.21	1.68
Aug	0.01	0.52	0.02	0.81
Sep	0.03	2.50	0.02	1.61
Oct	0.18	0.15	0.03	0.30

Mass Balance
Watershed as source or sink of nitrate


200
150
100
50
0
Load (kg-NO3-N)
Input
Predicted Load
Apr
May
Jun
Jul
Aug
Sep
Oct
2003
200
150
100
50
0
Load (kg-NO3-N)
Input
Observed Load
Apr
May
Jun
Jul
Aug
Sep
Oct
2003

Conclusions

SWAT needs modifications in cycling pathways and algorithms to be used effectively as a prediction tool in the study area.

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Talisman Energy Inc.
Alberta Innovates BioSolutions.
Forest Resource Improvement Association of Alberta
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