Simulating *Nothofagus* forests in the Chilean Patagonia: a test and analysis of tree growth and nutrient cycling in SWAT

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Outline of Presentation

- Basin characteristics
- Nitrogen cycling in Patagonia
- Potential problems and questions
- Objectives and methodology
- SWAT hydrological calibration validation
- Results - nutrient cycles
- Discussion
- Conclusion

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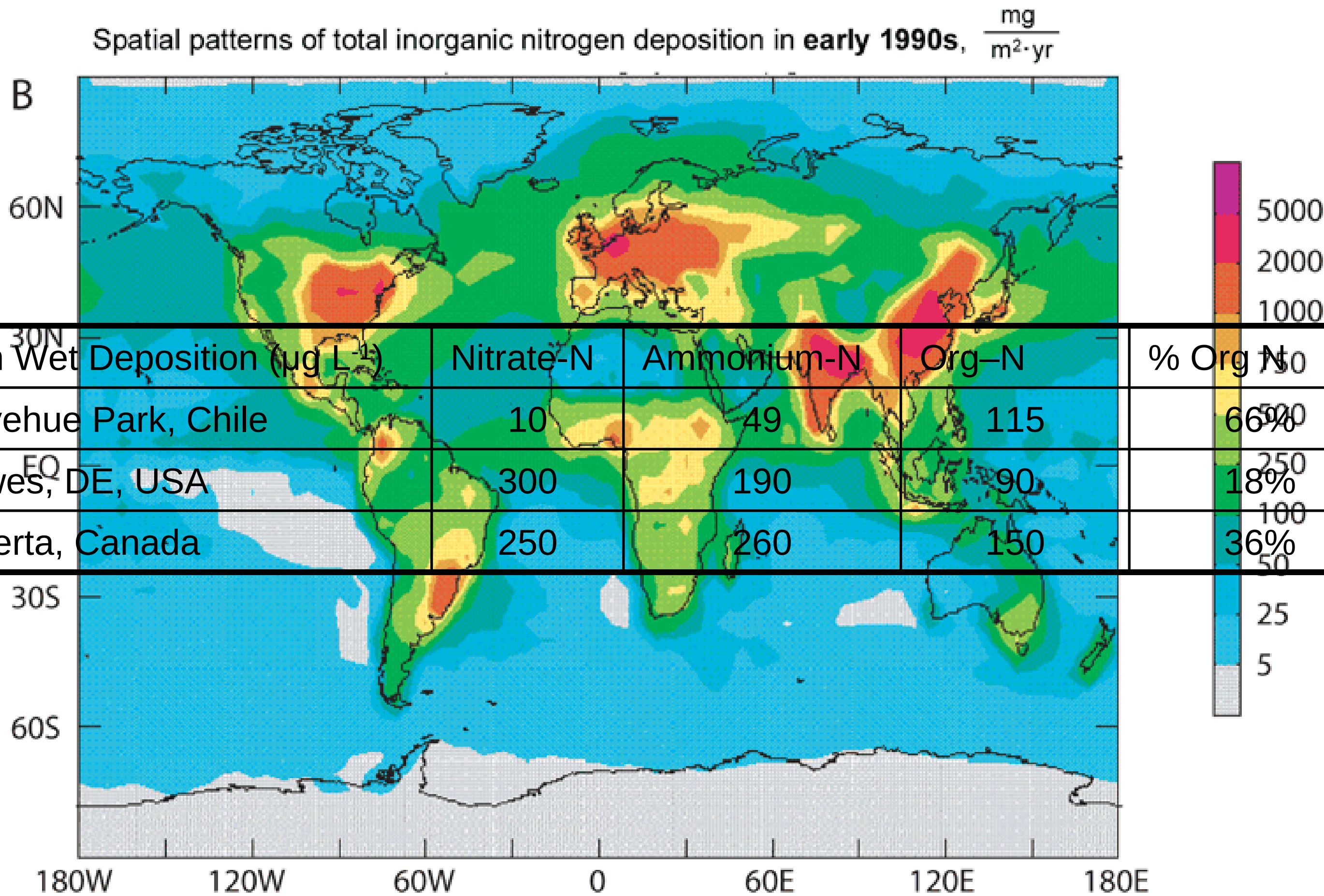
Nitrogen cycling in Patagonia: Inputs

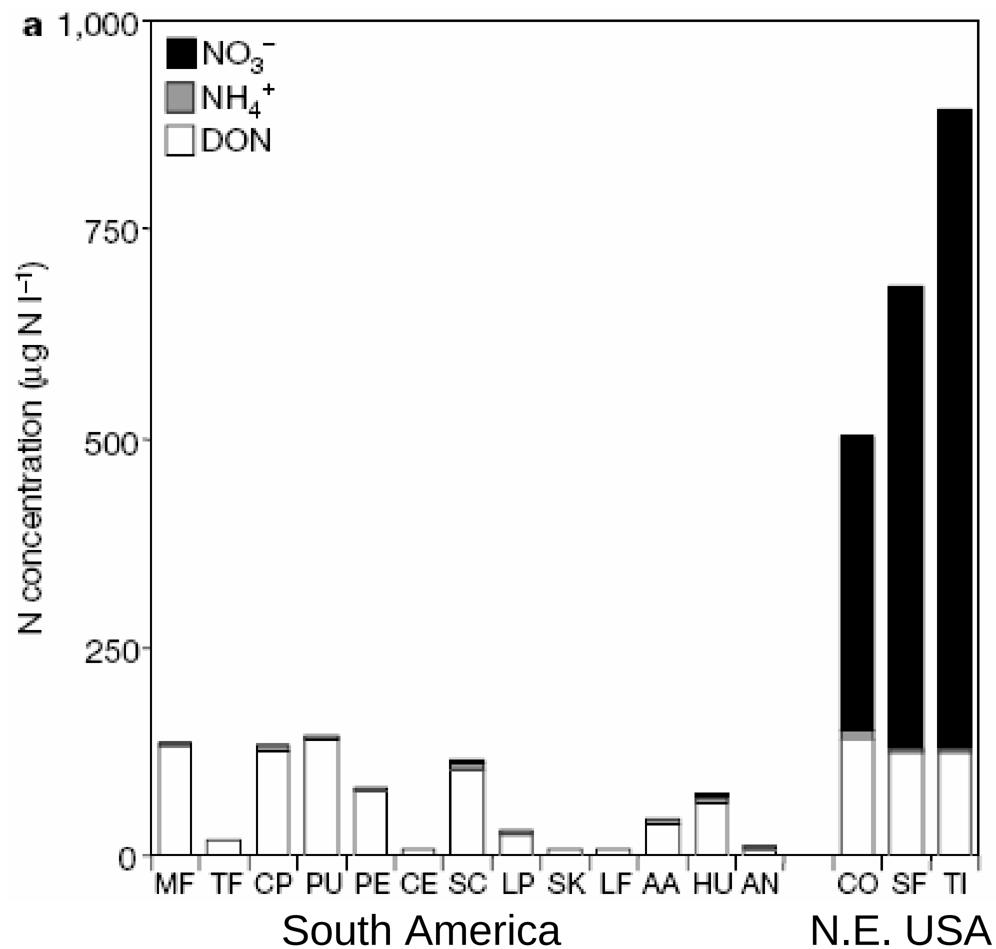
Patagonia: Among lowest rates of wet N deposition in World's temperate forests. Point of comparison with forests in N. hemisphere that receive excess N from human activities.



N in Wet Deposition ($\mu g\ L^{-1}$)	Nitrate-N	Ammonium-N	Org–N	% Org N
Puyehue Park, Chile	10	49	115	66%
Lewes, DE, USA	300	190	90	18%
Alberta, Canada	250	260	150	36%

Nitrogen cycling in Patagonia: Outputs

Hydrologic N losses from temperate forest watersheds in southern South America and eastern North America



•Simulation models that include nitrogen cycling often assume that nitrogen outputs in temperate climates are inorganic, especially nitrate and ammonium.

•Human activities such as fossil fuel combustion, fertilizer production and land-use change have altered the nitrogen cycle in the northern hemisphere.

•Patagonia: Wet deposition and outputs often dominated by organic forms: represent an important test of models and assumptions from the northern Hemisphere.

(Perakis & Hedin 2002)

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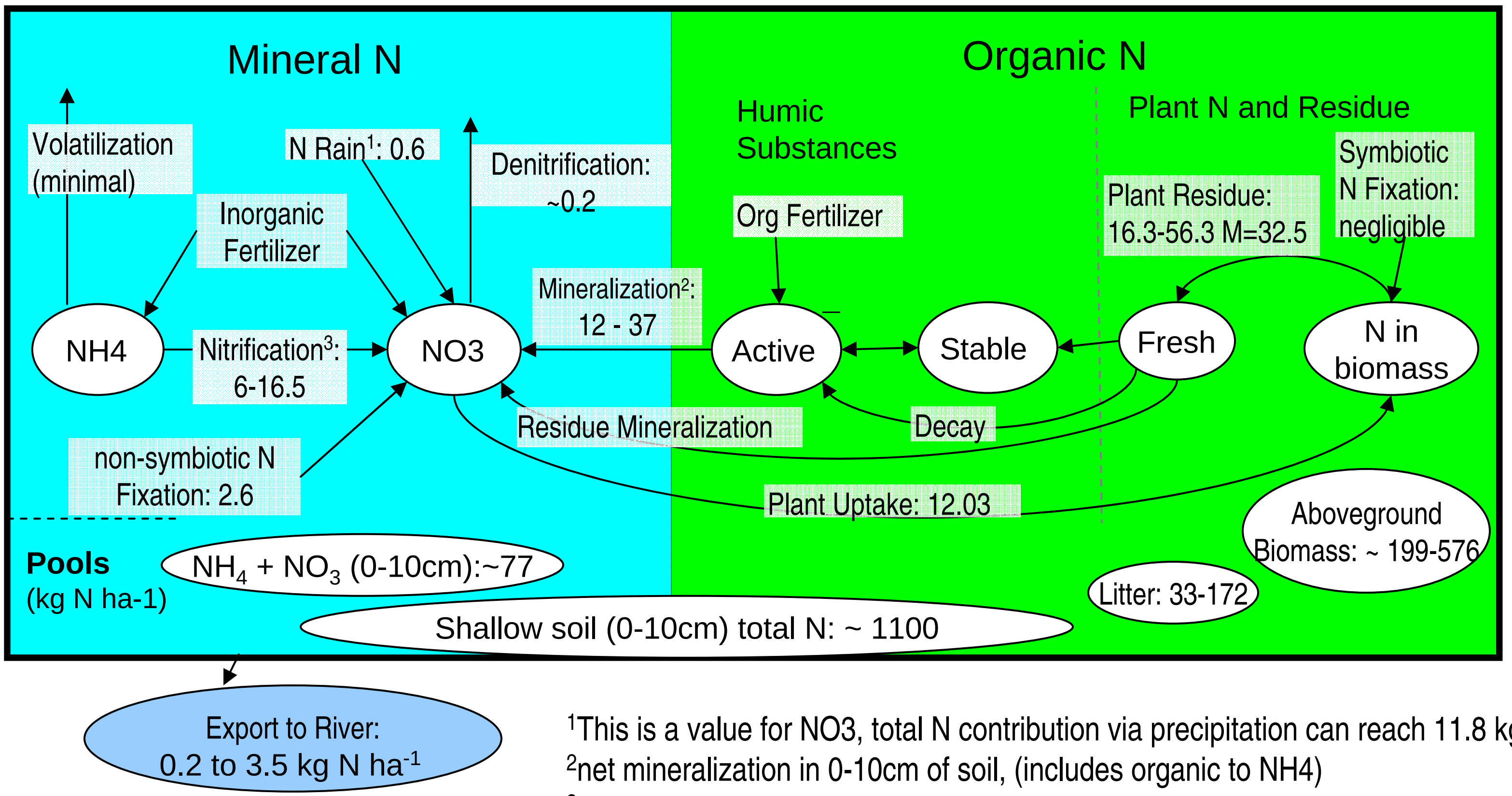
Nitrogen cycling in Patagonia: Inside the box

Diagram of N cycle in SWAT2005 with pools and process rates for Patagonian forests taken from the literature. (Diagram adapted from SWAT2005 Theory)



[1]This is a value for NO3, total N contribution via precipitation can reach 11.8 kg ha-1 yr-1

[2]net mineralization in 0-10cm of soil, (includes organic to NH4)

[3]nitrification estimated as 50% of net mineralization (Perez et al. 1998)

(Diagram adapted from SWAT2005 Theory)

N cycling in Patagonia: Potential problems and questions

Users applying SWAT to unique basins should proceed with caution in order to make sure modeled processes in SWAT fit with what is known about a particular basin.

Tree growth and organic residue

- SWAT inherited plant growth algorithms from EPIC model – created for agricultural settings, What are consequences for forested basins?
- Because exogenous nutrient inputs into forests systems in southern Chile are minimal, litterfall is an important source of bioavailable P and N. Is residue production in SWAT reasonable?

Too much N in wet deposition

- The default value of the RCN parameter (nitrate in precipitation) in SWAT is 1 mg/L.
- Can better results might be obtained if the N in precipitation could be divided into its major fractions (NO3, NH4, DON) and introduced directly into the appropriate pools?

Tree classes in Crop database

- Default crop types for forested systems are limited.
- Can custom crop classes aid in approximating the unique N cycles in Patagonian forests?

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N cycling in Patagonia: Objectives and Methods

<u>Objectives:</u>

- Approximate pools and fluxes of N in a Patagonian watershed by fine-tuning existing algorithms in SWAT and without incorporating a full accounting of the carbon cycle. (rationale: maintain simplicity, avoid additional data needs)

- Produce a SWAT output file that expedites the visualization and analysis of nutrient cycles for the entire basin and for different types of HRU.

<u>Methodology:</u>

- Adjustment of N input in precipitation by modifying SWAT to accept major N fractions (NO3, NH4, DON)
- Creation of custom crop types for Patagonian forests,
- Manual calibration aimed at approximate pools and fluxes of N
- Modify SWAT according to MOHID philosophy to produce output files that include all nutrient pools and fluxes (Chambel-Leitão et al. 2007).
- Create a macro in MS Excel in order to facilitate the visualization and analysis of nutrient cycles.

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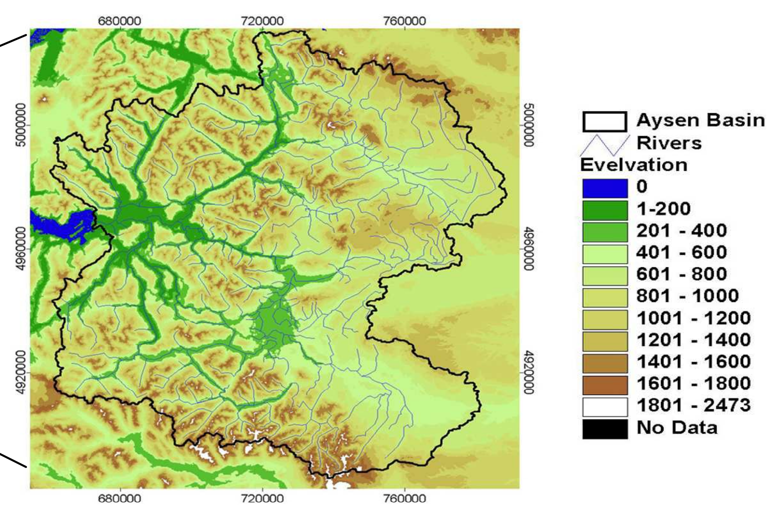
Aysén River Basin: Location and Characteristics

The Aysén Basin is located between 45°S and 46°S

- Surface area: 11,456 km^2
- Mean slope: 16.5%
- Strong precipitation gradient:
  >4000 mm yr^{-1} on west side to <600 mm yr^{-1} in east

Landuse:
Forested: 46.6% Pastures: 29.3% Wetlands 1.2%
Rock, snow/glaciers, tundra, unclassified areas: 21,3%
Urban and agricultural areas 0.2%



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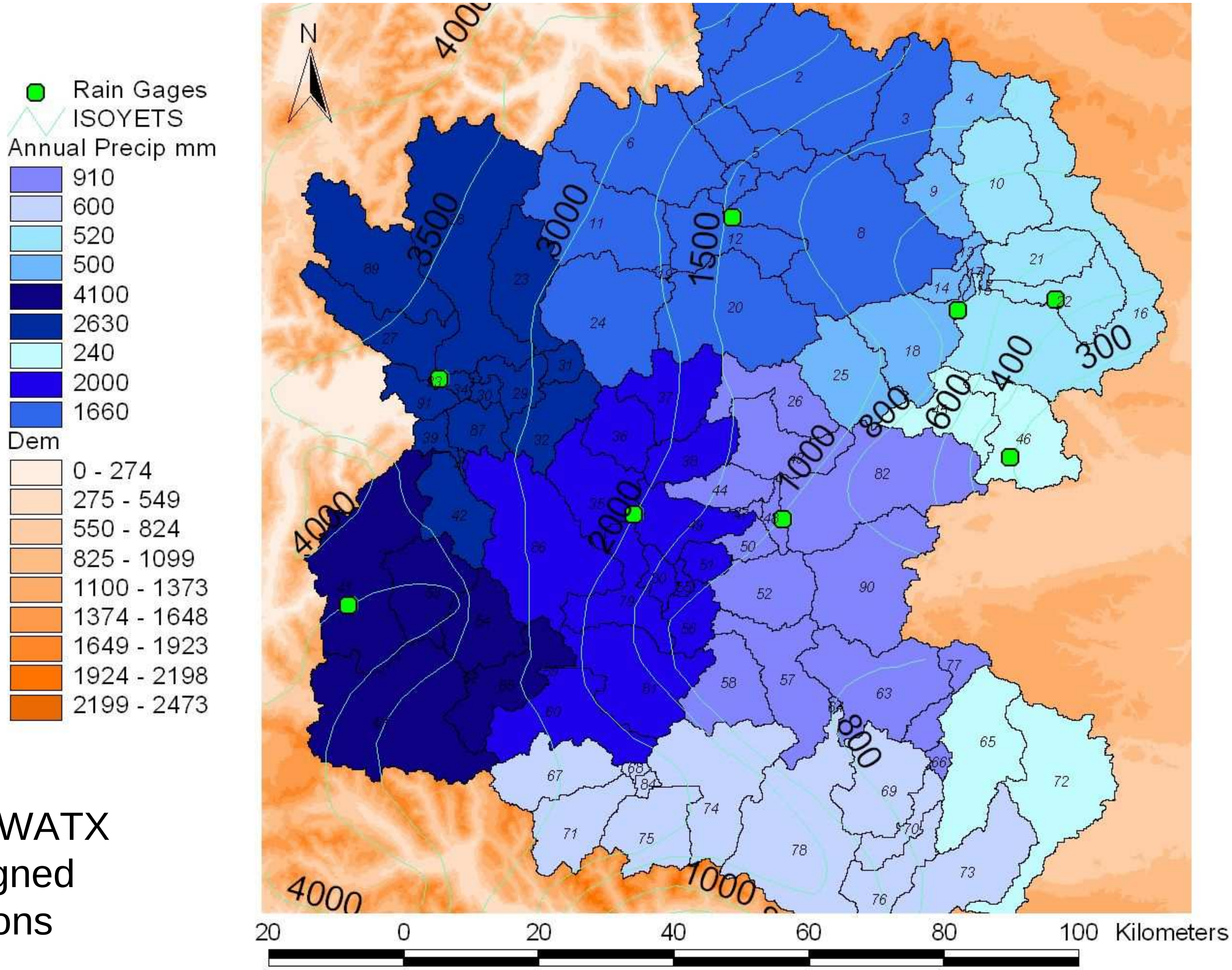
Aysén River Basin: Precipitation Station Setup



AVSWATX assigned stations

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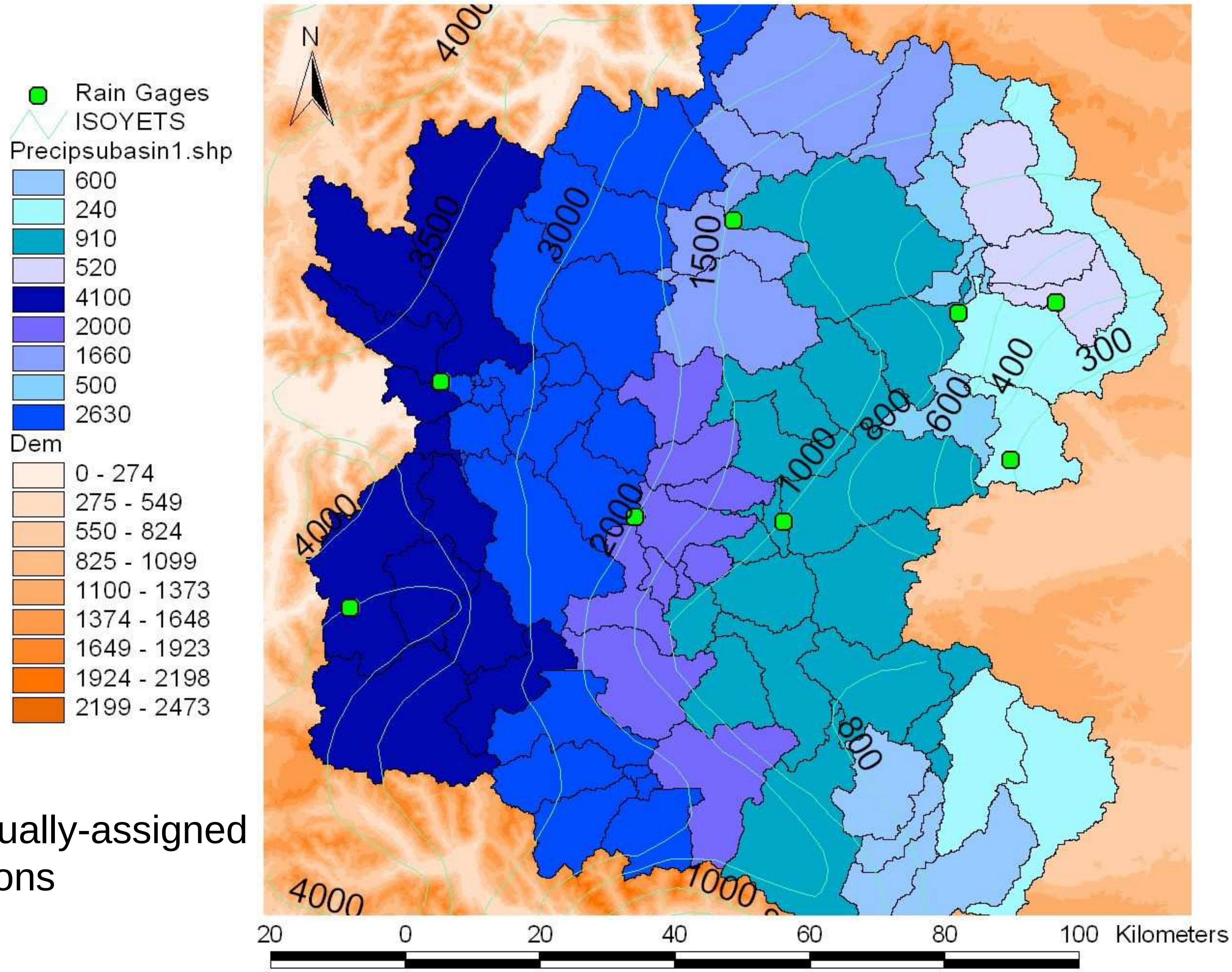

Manually-assigned stations

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Aysén River Basin: Vegetation

New SWAT Land Cover Classes and existing tree classes

SWAT Code	Vegetation Type	Principal Species	BIO_LEAF	BLAI	RDMX	CHTMX	HVSTI	T_BASE
BCAY	Deciduous forest of Aysén	*Nothfagus pumilio*	.8	4.8	2.5	15	0.05	0
MCAM	Montane deciduous forest	*N. antarctica, N. pumilio, Berberis* spp.	.8	4.2	2.5	15	0.05	0
BSNB	Montane evergreen forest	*Nothfagus betuloides, Laurelia philippiana*	.5	5	3	20	0.05	0
FRSD	Forest-Deciduous	Oak	0.3	5	3.5	6	0.76	10
FRSE	Forest-Evergreen	Pine	0.3	5	3.5	10	0.76	0

Aysén River Basin: Hydrodynamics

Comparison of observed and modeled average monthly flows and daily and monthly R^2 and model efficiency statistics

	Station	Time period	Observed / modeled flow (m^3/s)	R2 Day/Month	ME Day/Month
Calibration	Aysén	Jan ‘96–May ‘98	556/582	0.54/0.86	0.5/0.73
	Mañihuales	Jan ‘96–May ‘98	187/173	0.53/0.75	0.51/0.73
	Simpson	Jan ‘96–May ‘98	47/62	0.67/0.83	0.55/0.59
Validation	Aysén	Sep ’02-Sep ‘05	599/507	0.48/0.67	0.33/0.41
	Mañihuales	Jul ’02-Jul ‘05	201/167	0.52/0.79	0.5/0.7
	Simpson	Feb ’02-May’05	60/43	0.56/0.61	0.42/0.41

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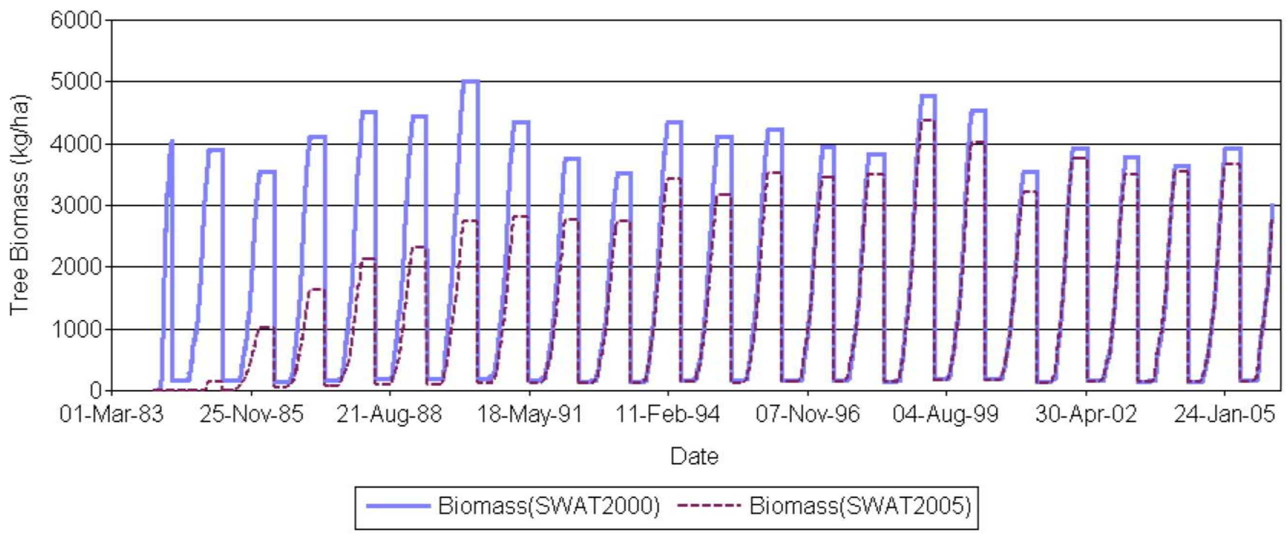
Aysén River Basin: Residue production

- In SWAT2000, interannual tree growth did not occur
- In SWAT2005, tree growth from sampling to mature tree is able to occur
- Under default tree parameter sets a large fraction of annual biomass production is removed as yield or converted to residue, resulting in minimal growth of persistent biomass
- Our strategy is to ignore total biomass of a forest system and calibrate residue production to achieve realistic nutrient cycling

Biomass production with SWAT2000 and SWAT2005 for *Nothofagus pumilio (BCAY)*.



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Comparison between measured litterfall and simulated residue for new land cover classes

SWAT Code	Vegetation Type	Range of litterfall (Mg ha-1 yr-1)	Simulated residue, range and mean (Mg ha-1 yr-1)
BCAY	Deciduous forest of Aysén	2.0 - 3.6	1.9 - 4.2; 2.93
MCAM	Montane deciduous forest	1.4 - 2.5	1.2 – 2.8; 1.94
BSNB	Montane evergreen forest	2.8 - 3.8	2.3 – 3.82; 3.19

Principal Sources: Caldentey et al. 2001; Austin & Osvaldo 2002; Vann et al. 2002; Pérez et al. 2003b

Aysén River Basin: Nutrient export

- The average measured NO3 value was 0.048 mg/l while SWAT NO3 output for the corresponding reach was 0.053 mg/l. This difference was not statistically significant (*t*= 0.91, *p*=0.37, *gl*=27).
- The same simulation set up, run with RCN = 1 gives a NO3 concentration in the reach of 0.23 mg/L, which is higher than even the highest measured value.

Estimated annual nitrogen and phosphorus loads from diffuse sources.

Simulation Run	N (tons/year)	P (tons/year)	% Org N
RCN = 1	7674	436	29%
RCN=1, N parameter set	4592	231	24%
NH4=0.049, NO3=0.01, DON=0.115, N parameter set	2776	288	56%

(N parameter set: RSDCO = 0.005, SDNCO = 0.95, NPERCO = 0.005)

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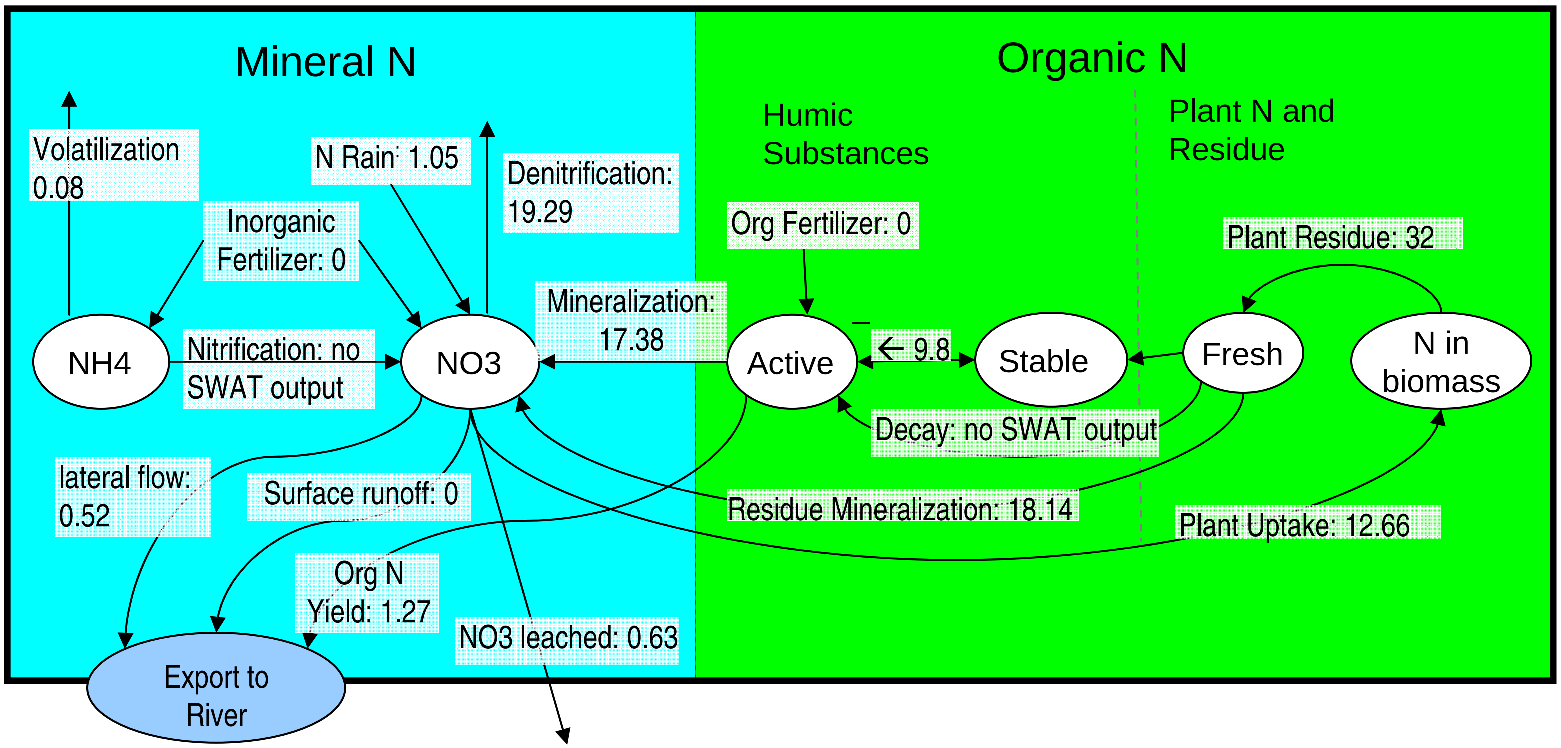
Aysén River Basin: Nitrogen cycle

•In general, the values of the annual N cycle processes are within the range of literature values given in the previous figure.

Output of SWAT2005 after calibration and changes for BCAY forest type (kg N ha-1 yr-1)



Discussion

- Denitrification: model and field data have a poor match.
  - CDN (denitrification exponential rate coefficient) was left at its default value. Further calibration may be waranted.
  - little published denitrification data may be too low for Aysén where the high rainfall and high organic soil matter should allow for more denitrification.
- Net mineralization occurs consistently during the simulation period.
  - This might act to drive more denitrification than would otherwise occur.
- A qualitative indicator is the ratio of external:internal N cycle fluxes.
  - Current setup gives a value of 0.4. This fits with statements by Pérez and colleagues (2003a) that the N cycle in Patagonian forests tends to be tight with much internal cycling.

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Conclusion

- Took steps to improve the performance of SWAT2005 in watersheds dominated by relatively unpolluted temperate forests.
- Strategy was to make incremental modifications instead of adding more complex routines requiring additional parameterization or input data.
- Improvement in results:
    - the ratio of organic N to inorganic N in river water has decreased as we have calibrated and then modified the model.
    - the annual fluxes in the SWAT N cycle for the BCAY cover class corresponded to those gleaned from the literature.
- We conclude that SWAT2005 is capable of simulating the N cycle in this unique forested system. However, with more data, new algorithms for forest dynamics would likely produce better results.

Conclusion

- We used a SWAT2005 version in which the source code was partially modified—the inputs and outputs of the model—using MOHID's code and programming philosophy (Chambel-Leitão et al. 2007). This has improved analysis and visualization of admittedly complicated N cycles in large basins. Furthermore, a macro created in Excel allows nutrient diagrams to be rapidly produced.
- Further work:
    - Identification the most pressing gaps in field data.
    - Production of a working set of tools and models for managers and policy makers for the Aysén Basin (ECOManage Project)
- Potential utility of using SWAT with the three wet deposition compartments (NH4, NO3, and DON) as a way to study the potential effects of increasing anthropogenic N emissions worldwide and the interactions between climate change and biogeochemical cycles.

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