Interactions between reactive nitrogen and the Canadian landscape: a budget approach

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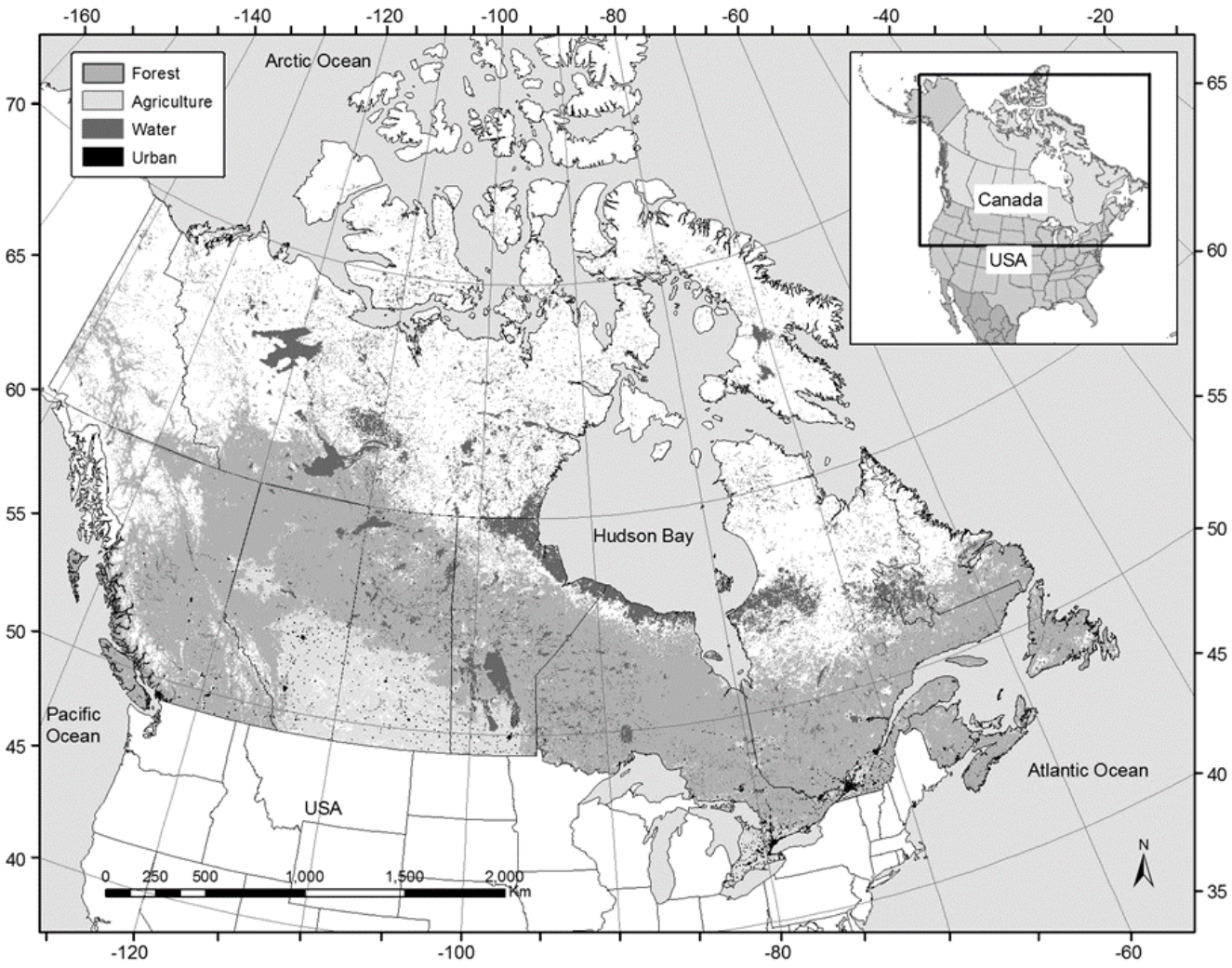
Landscape types south of 60°N used in this analysis. Natural/forest ecosystems occupy 83% of the surface area (4,874,726 km^2), lakes and open water 5% (313,472 km^2) and agricultural land 12% (682,356 km^2). Built environment occupies < 1% of the land surface (~58,700 km^2)



Why work at the landscape level?

- Canada is a very large country with a wide range of forest, agricultural and industrial activities which are quite separate and easily quantified
- This is not an ‘official’ budget, so we did not want to get involved in policy issues which would have required participation from another layer of people.

Where did data for a landscape budget come from? – Canadian government data bases and published literature

- **Industrial emissions – National Pollution Release Inventory (NPRI)**
- **Agricultural emissions – Agric. and Agrifood Canada and NPRI**
- **Deposition – AURAMS*, Moran et al.**
- **Forestry – University of New Brunswick, Arp, Murphy et al.**
- **River N exports – Clair et al.**
- **Fertilizer, agric., forestry, petroleum – Nathan Pelletier, Dalhousie University**

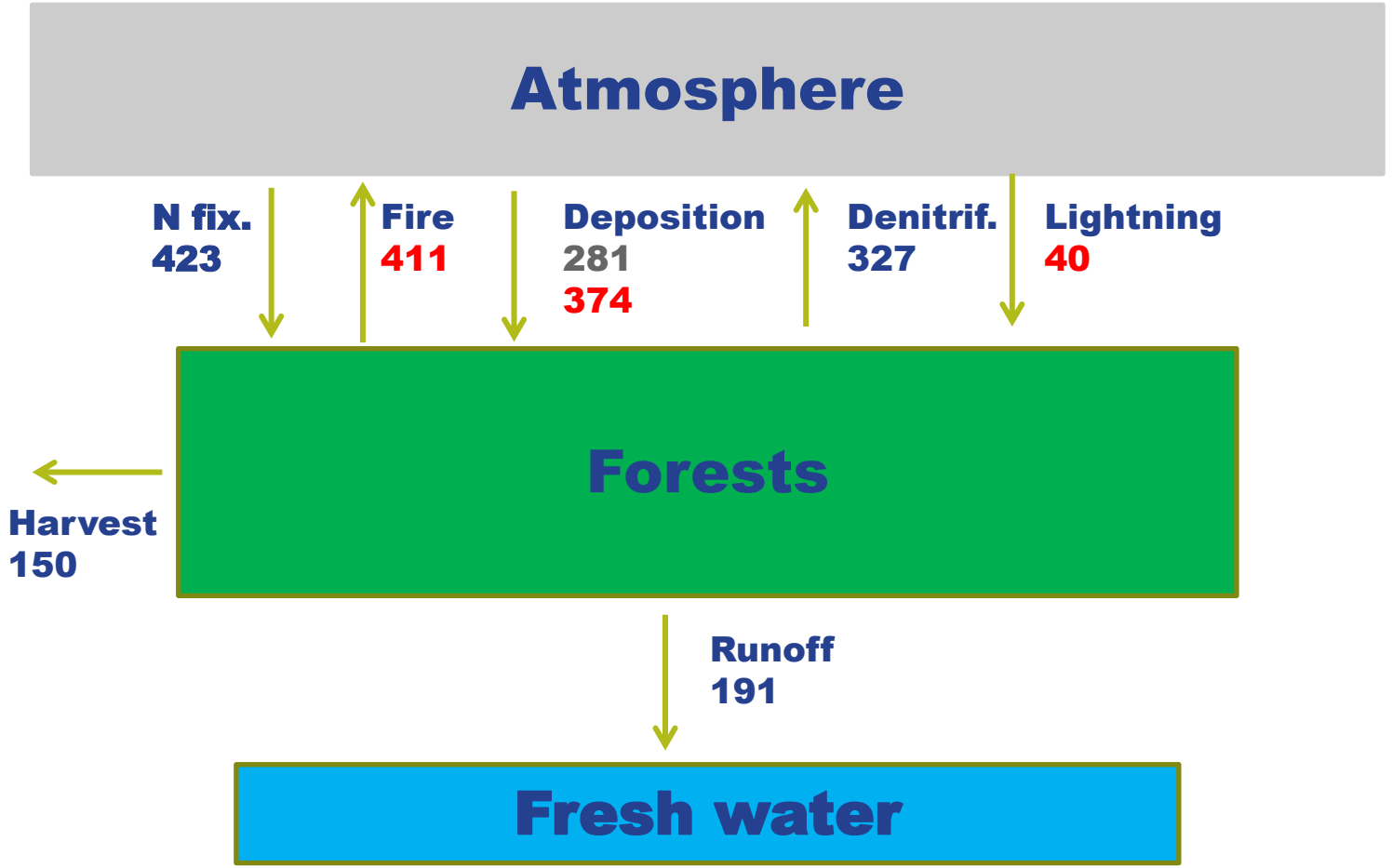
Data for the year 2007 +/- 2 years

*A unified regional air-quality modelling system

Methods

- We used the TFRN EPNB spreadsheet template to assemble the necessary data
- We used GIS approaches to divide Canada into landscape types: forests, agriculture, urban, freshwater. We used only information south of 60^{o} N as little anthropogenic activity in northern Canada

Forests and natural systems



Main components of the forest/natural landscape unit
Values in kton-N/year, numbers in red are oxidized N and in blue reduced or organic

N_r budget for forest and terrestrial natural ecosystems. All values in kton yr^{-1}

Inputs		Losses	
Atmospheric deposition	655	Harvest	150
N_2 fixation	423	Fire	411
Lightning	40	Denitrification	327
		Runoff	540
Total	1118		1428
Difference			-310

Conclusions - forests

- The forest/natural landscape unit showed a close balance between inputs and outputs as our data estimated N losses exceeded inputs by ~22%. As most of the values we used in quantifying flows in this landscape were model estimates, this discrepancy is not surprising.
- Canadian forests are not N saturated in contrast with the situation in northeastern US where N saturation is evident in a number of regions

Agricultural Systems

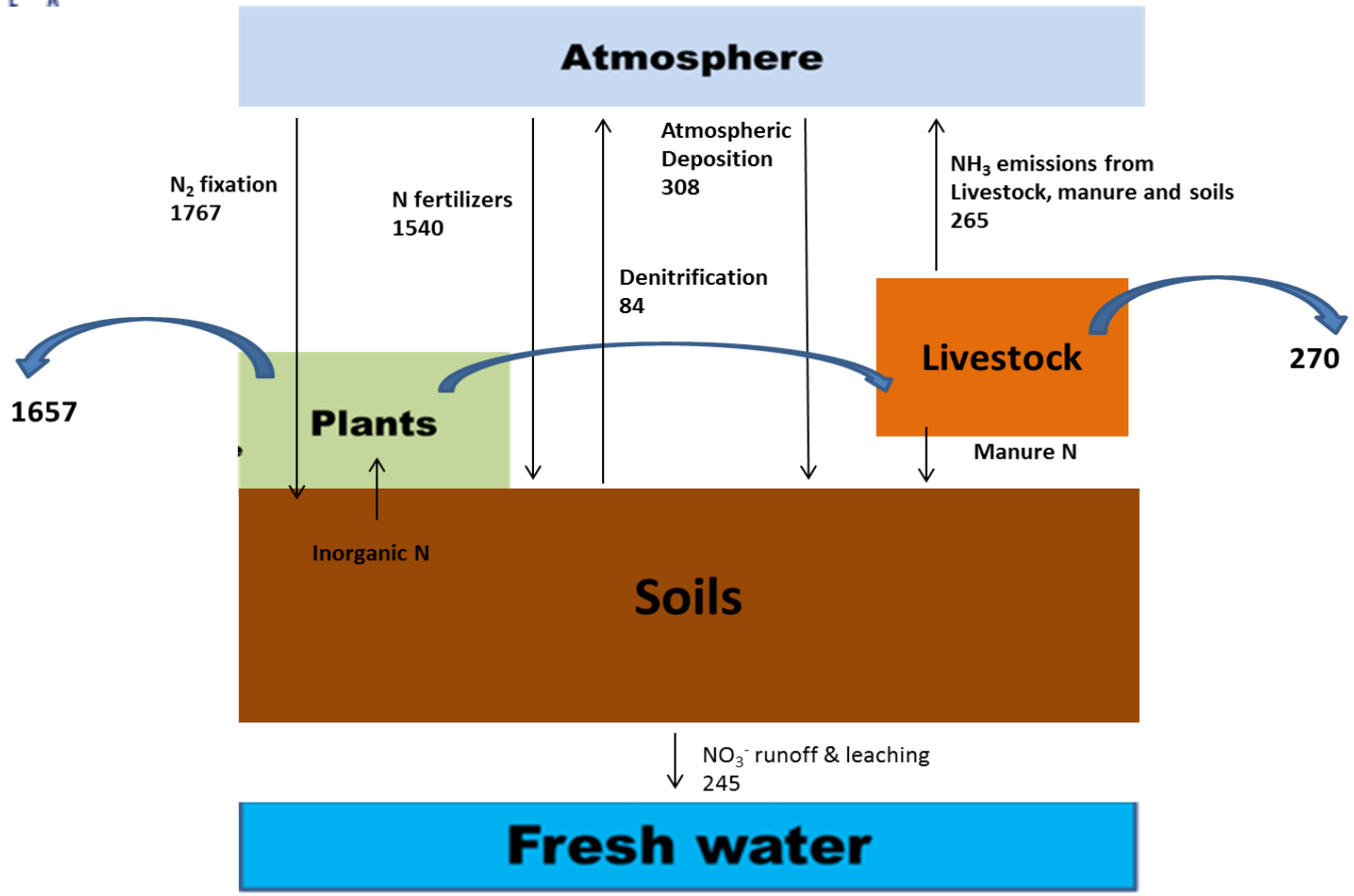


Figure 3. Main components of the agricultural landscape unit. Values in ktonN/year, numbers in red are oxidized N and in blue reduced.

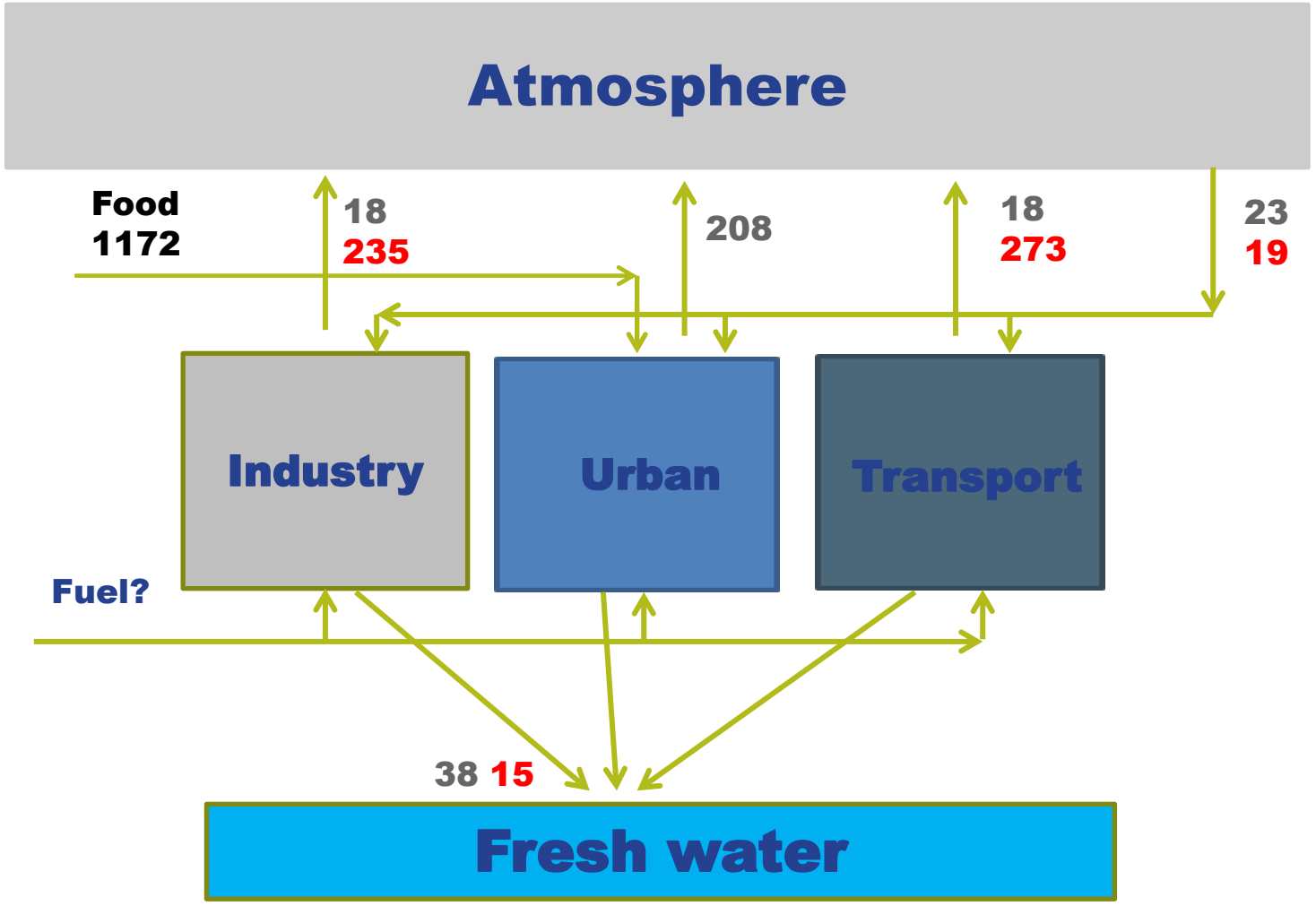
N_r budget for agricultural systems. All values in kton yr^{-1}

Inputs		Losses	
Atmospheric deposition	308	Crops (excluding feed)	1657
N_2 fixation by legumes	1581	Meat	270
N2 fixation by soil microbes	186	Denitrification	84
Fertilizers	1540	Runoff and leaching	245
		NH3 volatilization (soils)	122
		NH3 volatilization (animals)	143
Total	3615		2521
Difference			-1094

Conclusions - Agriculture

- Agricultural systems had the highest N inputs and exports of the landscape units we studied. We estimate a retention of +1094 kton N for Canadian agricultural soils in that year.
- Our retention number is roughly twice the US estimate of 17% of applied N being retained in agricultural lands

Urban/Industrial Component



Main components of the Urban/Industrial landscape unit. Values in ktonN/year, numbers in red are oxidized N and in blue reduced.

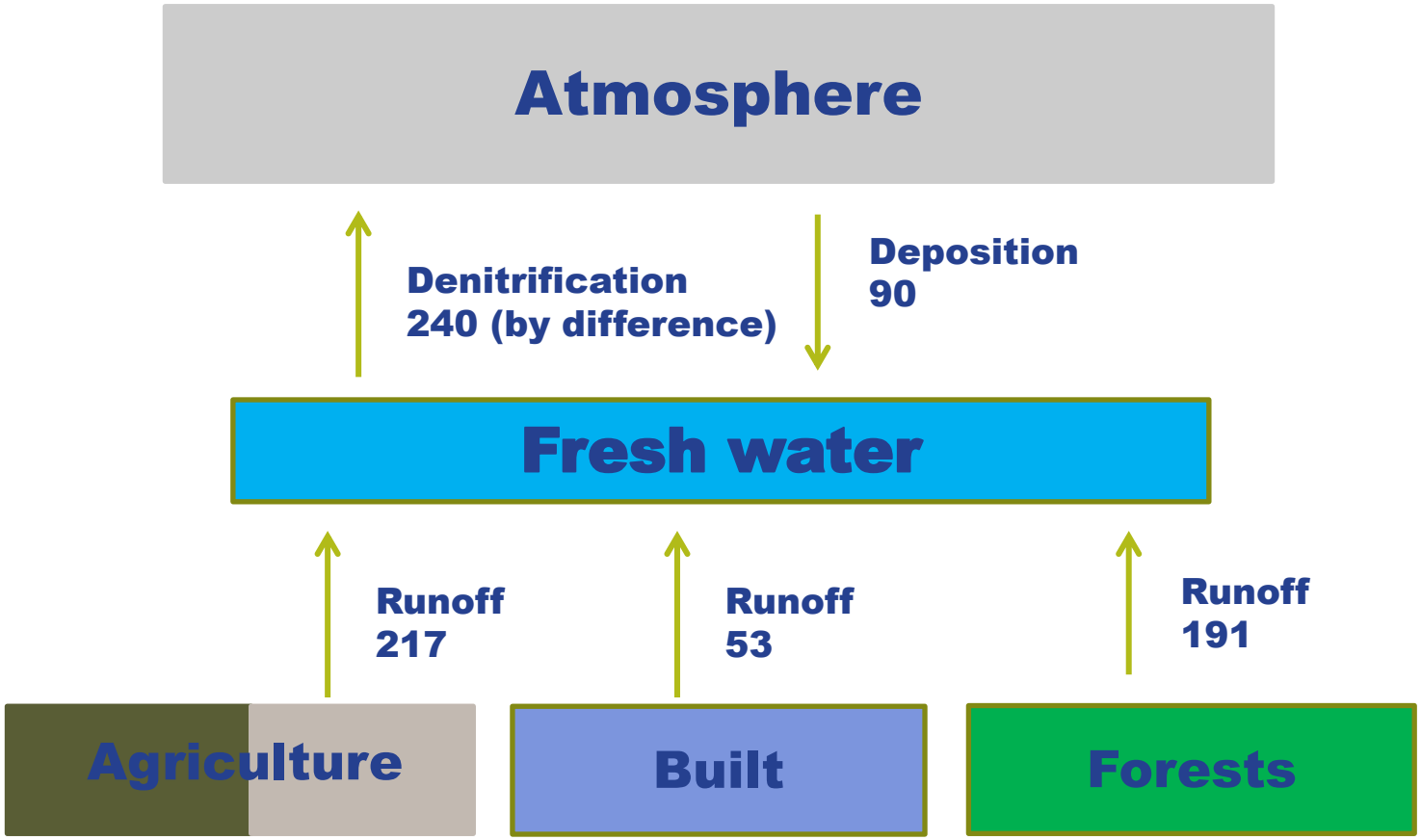
Table 3. N_r budget for urban/industrial systems. All values in kton yr^{-1}

Inputs		Losses	
Atmospheric deposition	42		253
Food	1127	Transportation	291
Fuel	290	Landfills (atmospheric)	4
		Sewage .(atmosphere)	204
		Sewage (water)	137
		Urban runoff	9
Total	1459		896
Difference			563

Conclusion – Urban/Industrial

- our estimate of N inputs is overly simplistic and an understatement. Nevertheless, we note that even with an incomplete assumption of inputs, losses from the urban/industrial/transportation sectors are considerably less than what is input into this system, which may be attributed in part to N in manufactured goods.
- N losses from the urban/industrial landscape: 80% are discharged into the atmosphere and 20% into water.

Fluxes to freshwater



Values in ktonN/year.

N_r budget for freshwaters. All values in kton yr^{-1}

Inputs		Losses	
Atmospheric deposition	90	Export from rivers	753
Agriculture	217		
Sewage treatment	137		
Urban runoff	9		
Forests	540		
Total	993		753
Difference			240

Conclusions - freshwaters

- The largest N input into freshwaters comes from forest soil leachates, which are mostly in the form of dissolved organic nitrogen (DON)
- When all N inputs into freshwaters from Canadian sources were compared to exports from rivers to estuaries there was a loss of 24% of total N mostly due to denitrification. This loss was considerably lower than literature values which ranged from 50-60% because of the resistance to denitrification of forest soil leachates which dominate Canadian waters

Atmospheric fluxes

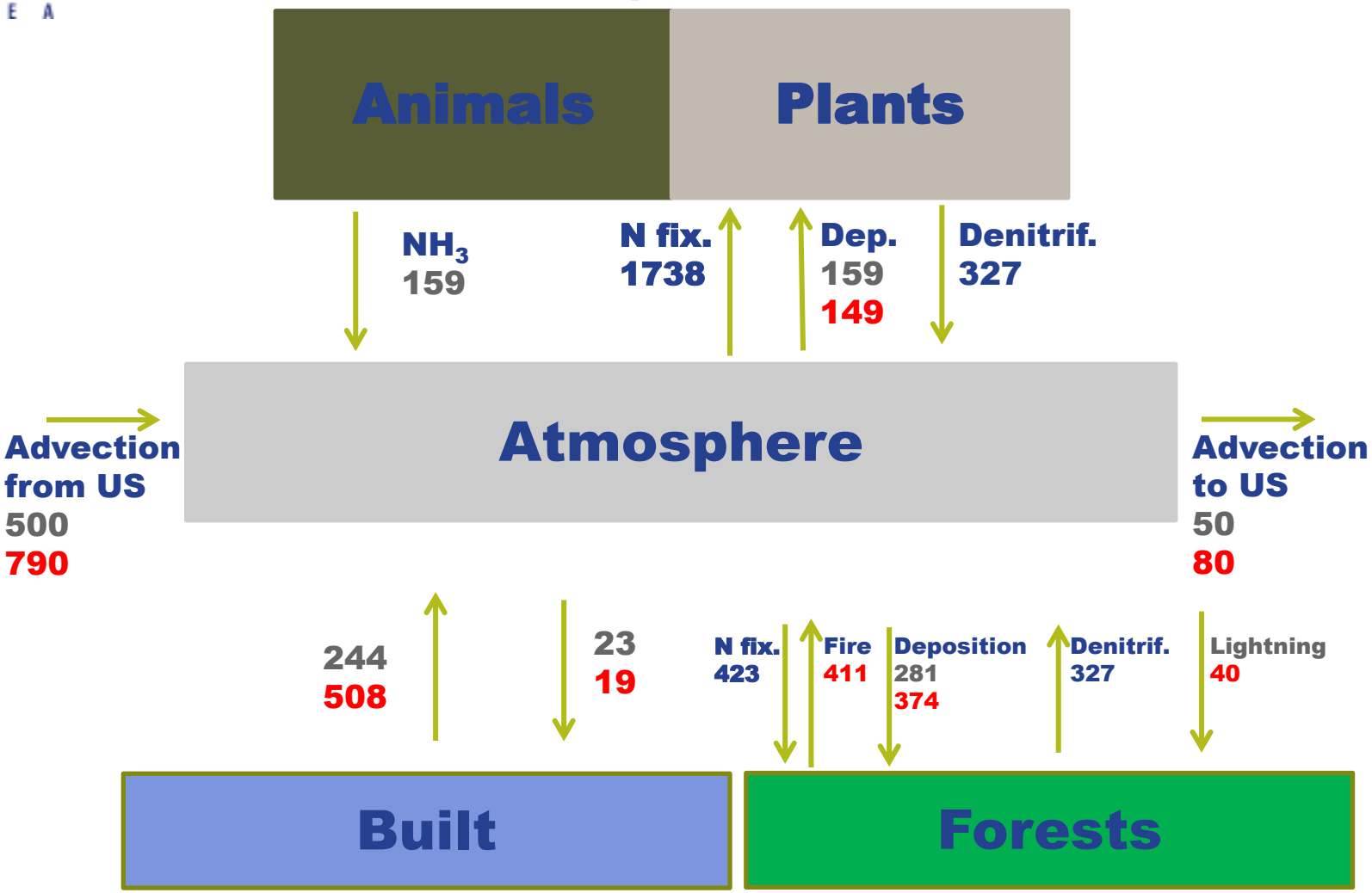


Figure 6. Main components of the atmospheric landscape unit. Values in ktonN/year, numbers in red are oxidized N and in blue reduced.

Table 5. N_r budget for the Canadian atmosphere. All values in kton yr^{-1}

Inputs into atmosphere		Losses from atmosphere	
Transboundary	1290	Transboundary	130
Forests/Natural systems (fire,denitrification)	738	Forests/Natural (deposition., fixation, lightning)	1118
Agriculture (denitrification, NH_3 volatilization)	349	Agriculture (deposition, N fixation)	2075
Urban/industrial (industry, transport, urban emissions)	752	Urban/industrial (deposition)	42
total	3129		3365
Difference			-236

Conclusions - Atmosphere

- Nitrogen inputs into the Canadian atmosphere are dominated by the trans-boundary movement of oxidized N from the United States
- Natural forest processes emit almost as much N into the Canadian atmosphere in the form of denitrification products and NO_2 from forest fires as the transport/industrial/urban sector which is unlike the situation in Europe or the United States where natural systems produce only a small portion of emissions.
- Unlike other industrialized western countries, as natural processes are very important in overall N cycling due to the large scale of forests as well as the low population density of the country.

Imports and exports of N for Canada attributable to flows of traded commodities in 2007 (values in kton).

	Import	Export	Difference
Food	503	1303	-800
Hydrocarbons	871	2136	-1,265
Fertilizer	342	2025	-1,683
Wood	105	125	-20
Totals	1821	5589	-3768

Conclusions - Trade

- Canada exported 3768 kton N more than it imported in 2006, and is therefore one of the larger N exporters in the world based on *Galloway et al.* [2008] analysis of global trade and this exported N then becomes part of the reactive N cycle elsewhere.
- The N export value is greater than all inputs into the Canadian atmosphere

Final Conclusions

- **In a country as large and diverse as Canada, N_r control needs to be done on a regional or provincial level to be useful**
- **Data quality –more work needs to be done in terms of data quality especially in validating model results**
- **Canada is unique in its size and natural resources and the only other country to which we could compare our production and use probably is Russia**
- **Nr effects in Canada are low compared to US and Europe, though locally in cities and industrial regions, there may be health and ecosystem effects**