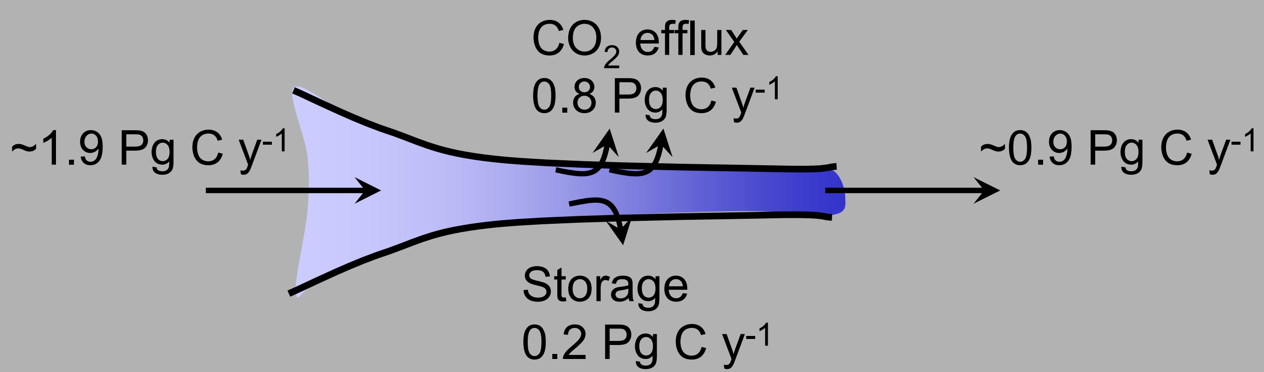
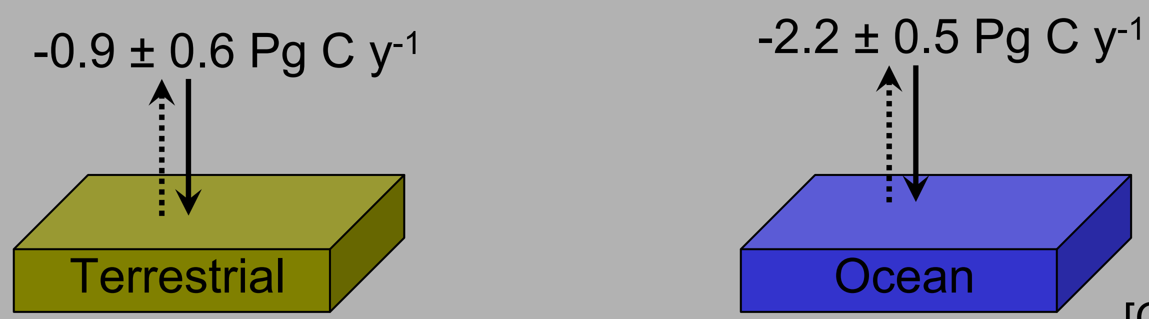
The role of freshwater ecosystems in carbon and nutrient cycling on the catchment scale

LSUE external launch – Steven Bouillon

Why are freshwater ecosystems important ?



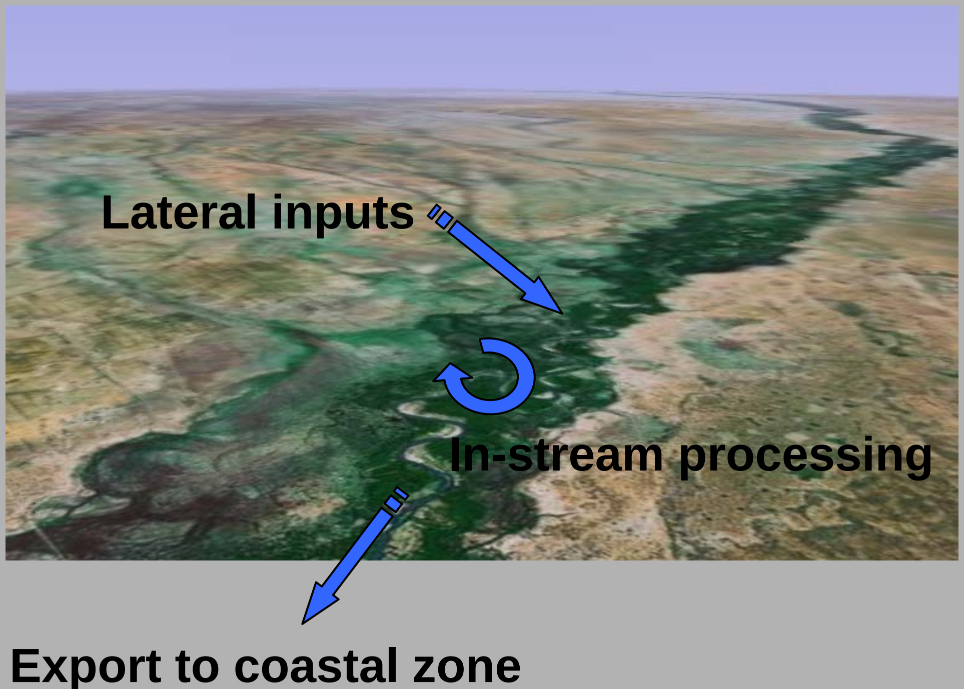


[Cole et al. 2007, Ecosystems]

→View on river systems changed from
"pipeline" to "reactor"
(same holds for estuaries, deltas)

→Disproportionally important in C cycling
relative to the area occupied

Why are freshwater ecosystems important ?



Lateral inputs known to be important, but:

► Quantification and upscaling difficult

► Link with catchment characteristics?

► Importance of in-stream processing ?
Quantititive
Qualitative

► Source characterization ?

► Anthropogenic influence ?
► Climate change infuence ?

Incorporation terrestrial-aquatic fluxes

Importance of aquatic C fluxes on catchment-scale: examples

1. Amazon basin [Richey et al. 2002, Nature]

Based on satellite data on flooded areas
+ field pCO_2 measurements:
Annual efflux of 210 10^{12} g C yr^{-1}

Extrapolated for the entire Amazon basin
470 10^{12} g C yr^{-1}

Compare with export of organic carbon
to ocean: 36 10^{12} g C yr^{-1}

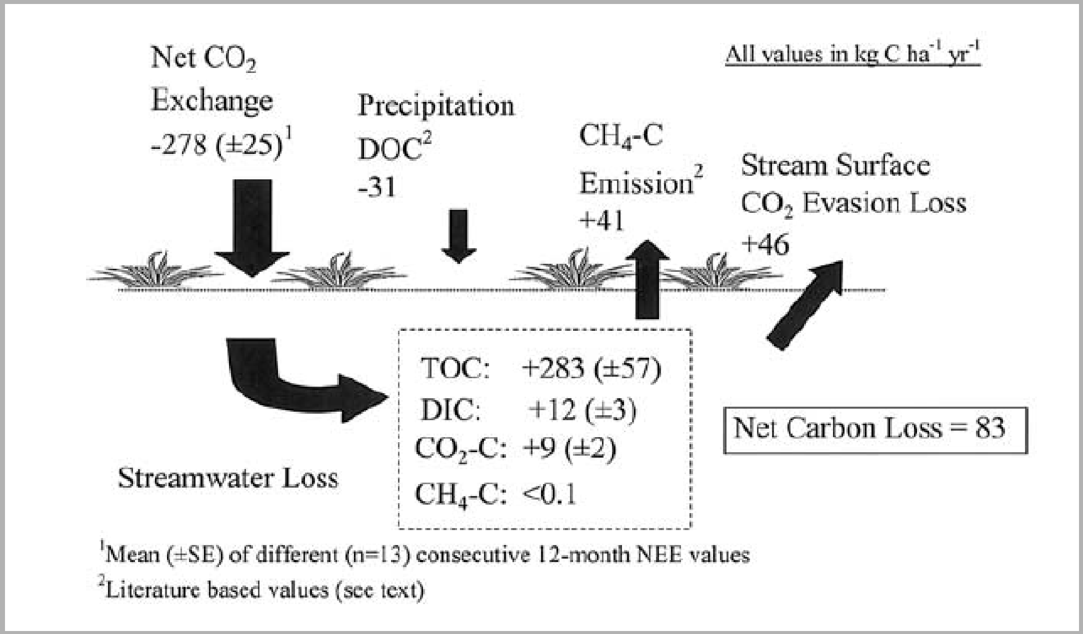
→Majority of C transferred to aquatic system is remineralized and evades back to atmosphere.

? How representative of other systems
? How reliable is upscaling effort and how critical is absence of data from floodplains

Incorporation terrestrial-aquatic fluxes

Importance of aquatic C fluxes on catchment-scale: examples

2. Peatland ecosystems



[Billett et al. 2004, Global Biogeochemical Cycles]

Riverine export of C exceeds Net CO_2 exchange over terrestrial part of catchment !

Looking only from terrestrial perspective: C sink

Combining terrestrial & aquatic: C source

Incorporation terrestrial-aquatic fluxes

Importance of aquatic C fluxes on catchment-scale: examples

3. Intertidal ecosystems
   - Mangroves: ~50 % of NPP exported as inorganic carbon, 10% as organic carbon [Bouillon et al. 2008 Global Biogeochemical Cycles]
   - Salt marshes
   - Mudflats

4. Forest ecosystems
   - e.g. spruce forest (Black Forest, G) [Fiedler et al. 2006, Sci. Tot. Env.]
     - ~15 g C m^{-2} y^{-1} exported (2:1 DIC:DOC)
     - NEE: -4 to -55 g C m^{-2} y^{-1}

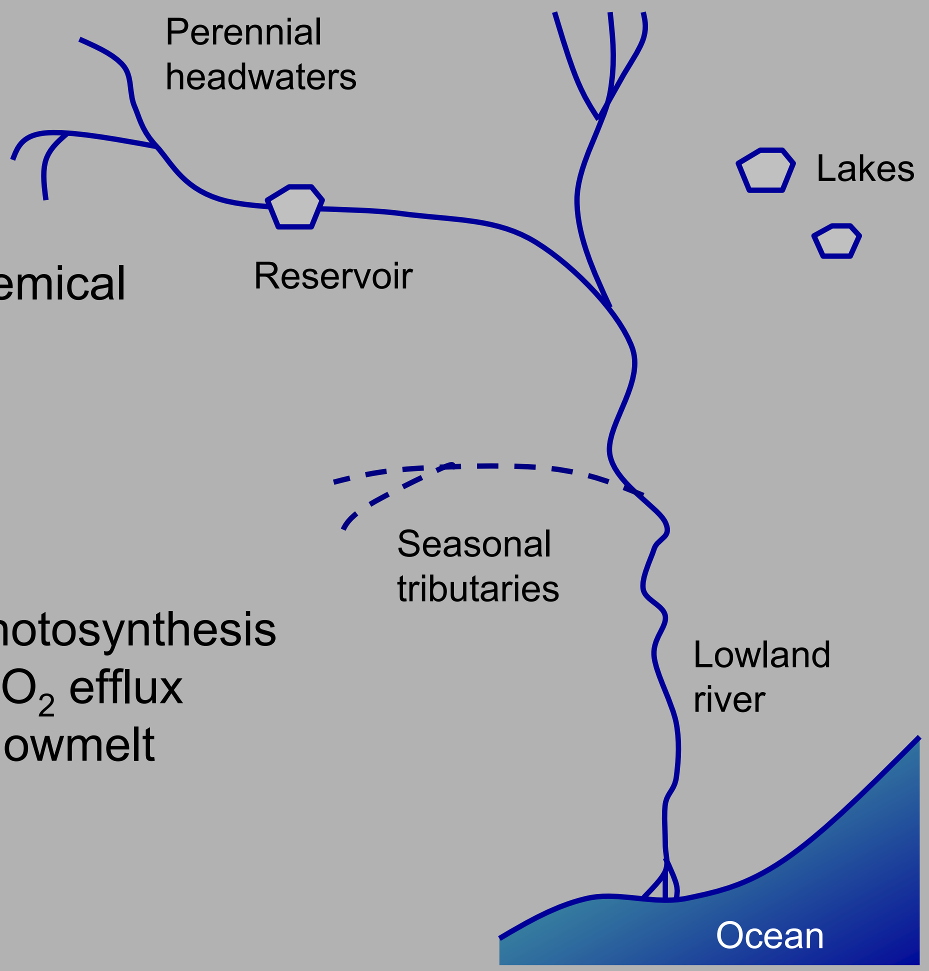
Problems in upscaling to catchment / global level

1. Diversity in ecosystems/compartments

2. “Hot spots” & “Hot moments”
[McClain et al. 2003, Ecosystems]

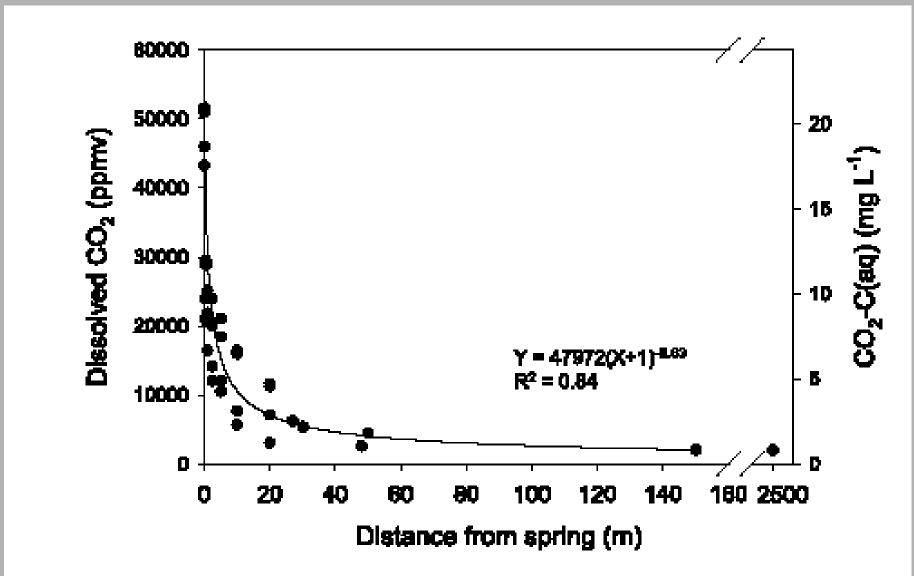
= isolated zones of enhanced biogeochemical cycling
=isolated periods of time with enhanced biogeochemical fluxes or process rates

Examples:
-reservoirs: enhanced sedimentation, photosynthesis
-upper reaches of streams: enhanced CO_2 efflux
-dissolved organic carbon pulse after snowmelt
-phytoplankton blooms



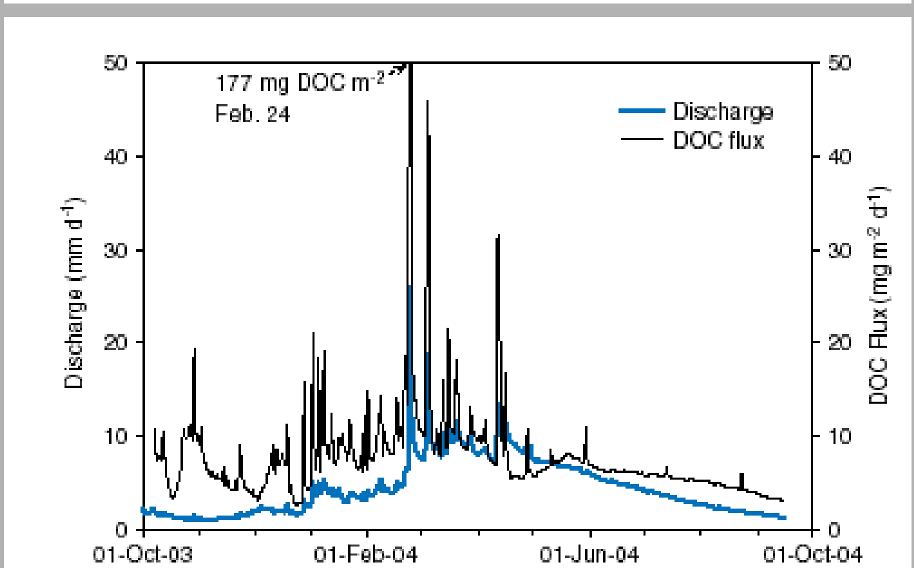
Problems in upscaling to catchment / global level

2. "Hot spots" & "Hot moments"



Johnson et al. 2008, Geophys. Res. Letters

Strong CO_2 evasion from upper part of headwater streams (soil-derived) in Amazon basin



Johnson et al. 2006, Hydrological Processes

Strong pulses in DOC fluxes in forested upper catchments in Amazon basin.

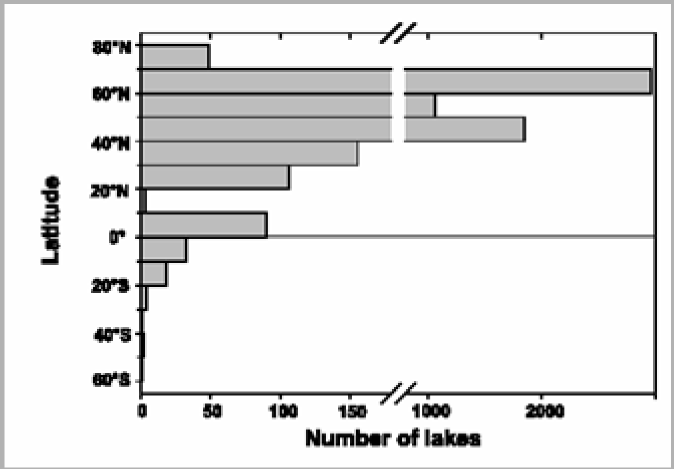
Problems in upscaling to catchment / global level

3. Variability in C, nutrient inputs or processing due to:

-land use, geology, soil type
-topography (runoff)
-climate, vegetation
-…

→Upscaling case studies requires sufficiently large datasets across natural gradient in ecosystem variability; combination of empirical data and modelling (empirical or process-based)
→Such datasets often lacking, or biased towards temperate zone

e.g. data compilation
on factors driving pCO_2 in lakes
Sobek et al. [2005]
~3 % of data from 20°S – 20°N



Problems in upscaling to catchment / global level

4. Taking into account different sources / origins of C and nutrients

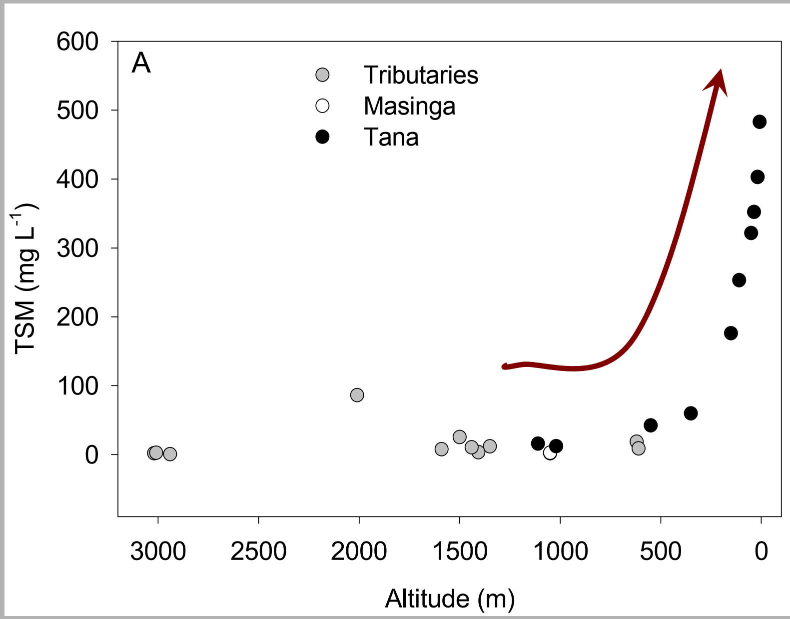
1/ Lateral C fluxes complicate ecosystem C budgets: C exchange between ecosystem boundaries

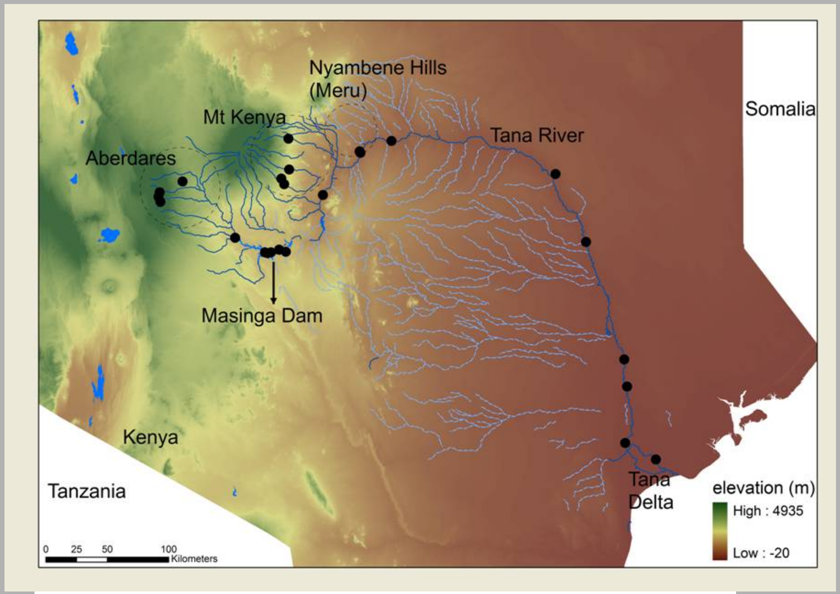
2/ Different sources of organic matter, e.g. terrestrial versus *in-situ* aquatic production

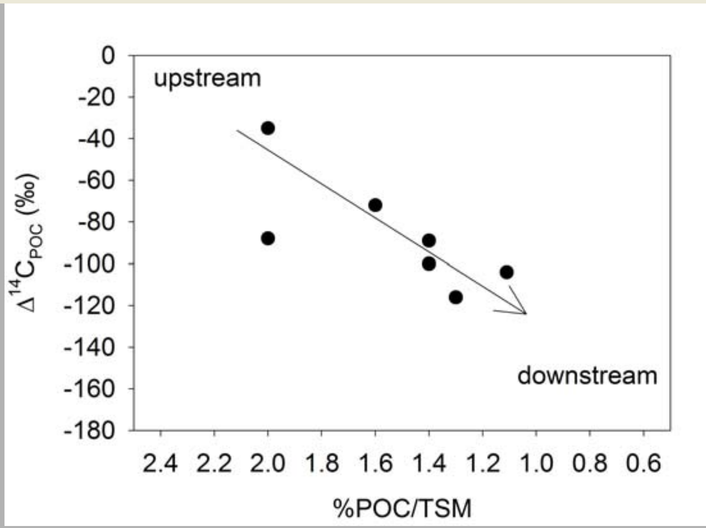
Problems in upscaling to catchment / global level

4. Taking into account different sources / origins of C and nutrients

Possible approaches
-stable isotope signatures
-^{14}C signatures
-molecular biomarkers





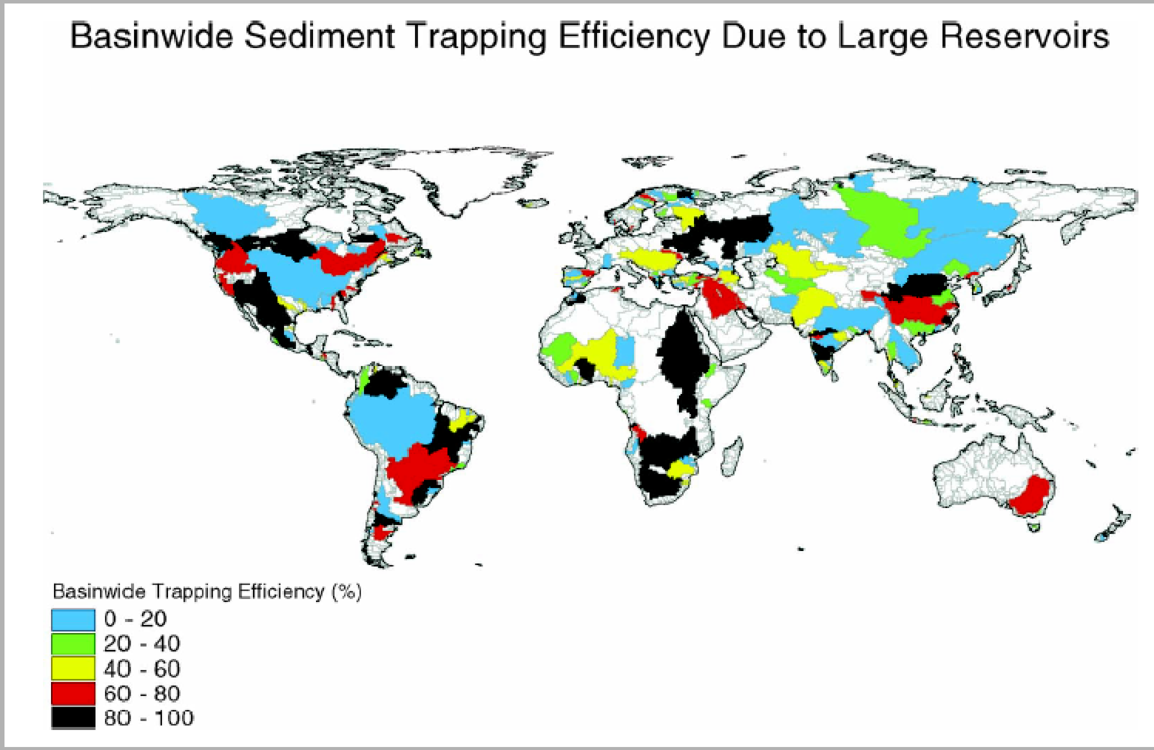


Aging of particle-associated C
in Tana River (Kenya)

Anthropogenic disturbances

Reservoirs and dams

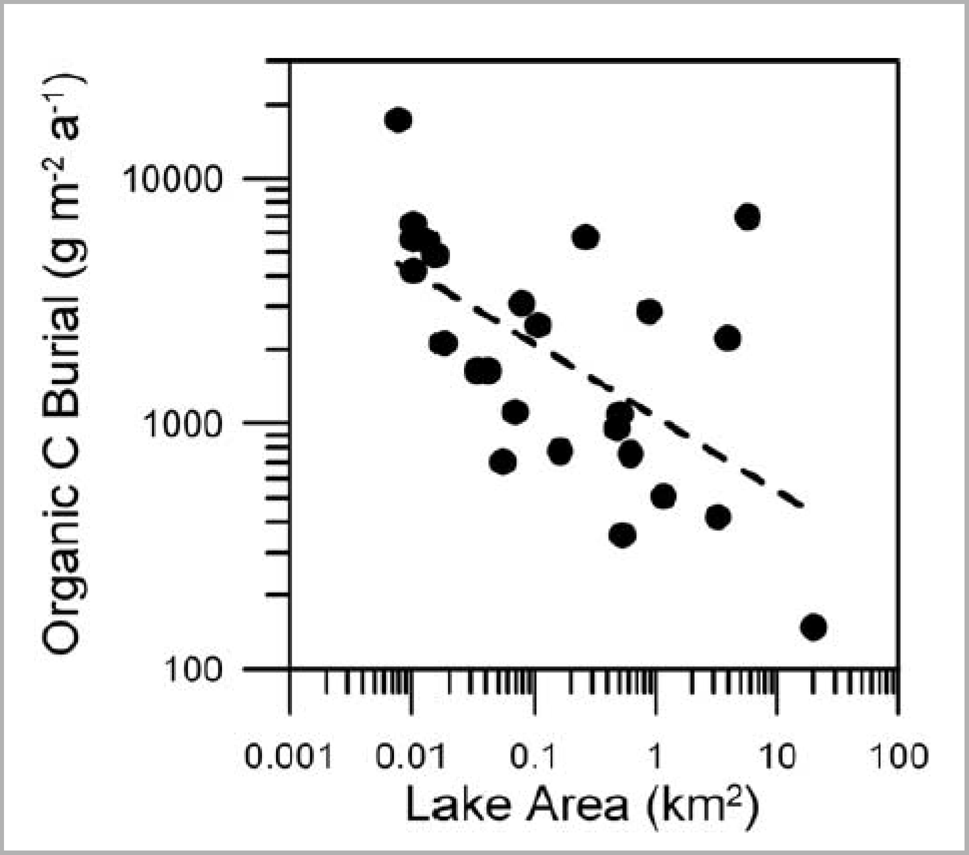
-effects on sedimentation (sink for associated organic C)
[Vörösmarty et al. 2003, Global & Planetary Change]



Globally: ~20% of transported sediment trapped in reservoirs
[Syvitski et al. 2005, Science]

Reservoirs and dams

-effects on sedimentation (sink for associated organic C)
[Downing et al. 2008, Global Biogeochemical Cycles]



Data from small agricultural impoundments

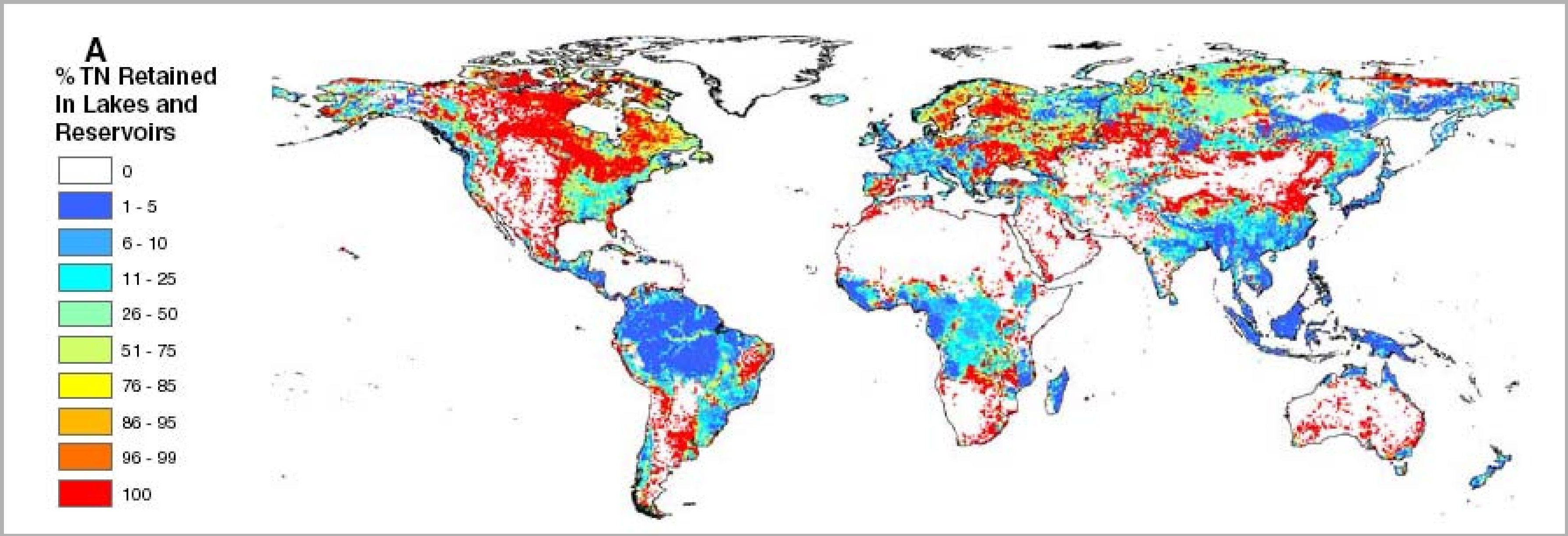
Reservoirs and dams

-larger reservoirs: anoxic bottom waters – potential CH_4 production
[from St. Louis et al. 2000, BioScience]

	Global surface area of reservoirs ($\times 10^6$ km^2)	Areal fluxes (mg · m^2 · d)		Global reservoir fluxes ($\times 10^{14}$ g/yr)			
		CO_2	CH_4	CO_2	CH_4	Total C	CO_2 Equivalents[a]
Temperate reservoirs	0.9	*1400*	*20*	3[b]	0.04[b]	0.7	3
Tropical reservoirs	0.6	*3500*	*300*	7	0.6	2	20
All reservoirs combined	1.5			10	0.7	3	23
Other anthropogenic emissions				260[c]	3.8[d]	74	339
% of anthropogenic emissions				4	18	4	7

Reservoirs and dams

-impact on nutrient retention
[Harrison et al. 2009, Biogeochemistry]

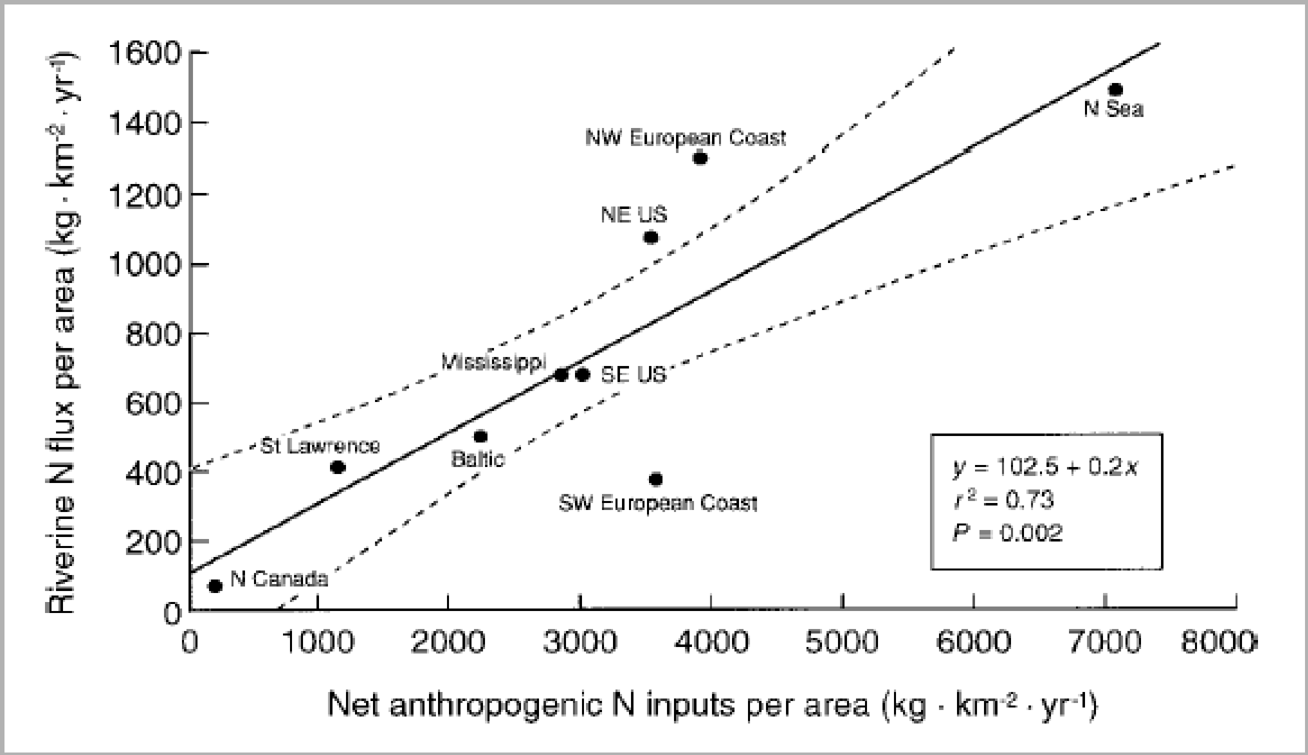


-N removal rates ~10 times higher in reservoirs compared to natural lakes

-small reservoirs and lakes disproportionately important

-similarly high potential impact on other nutrients, in particular Si

Land-use change and increased nutrient inputs - eutrophication



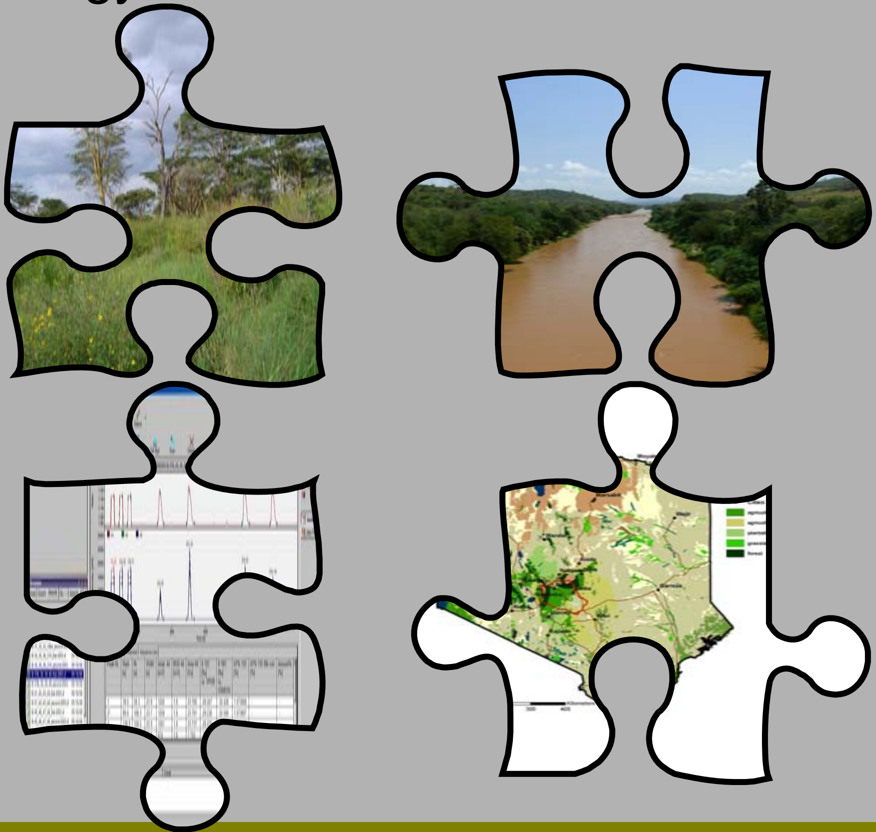
[From Vitousek et al. 1997, Ecological Applications]

2-20 fold increase in N export by temperate rivers into the N. Atlantic Ocean

Aquatic biogeochemistry within LSUE ?

Relatively new research direction – many opportunities to be developed, complementary expertise within LSUE is strong asset given complexity and scales considered:

terrestrial C cycling
surface and groundwater hydrology
land use changes
erosion
aquatic ecology
analytical work
modelling

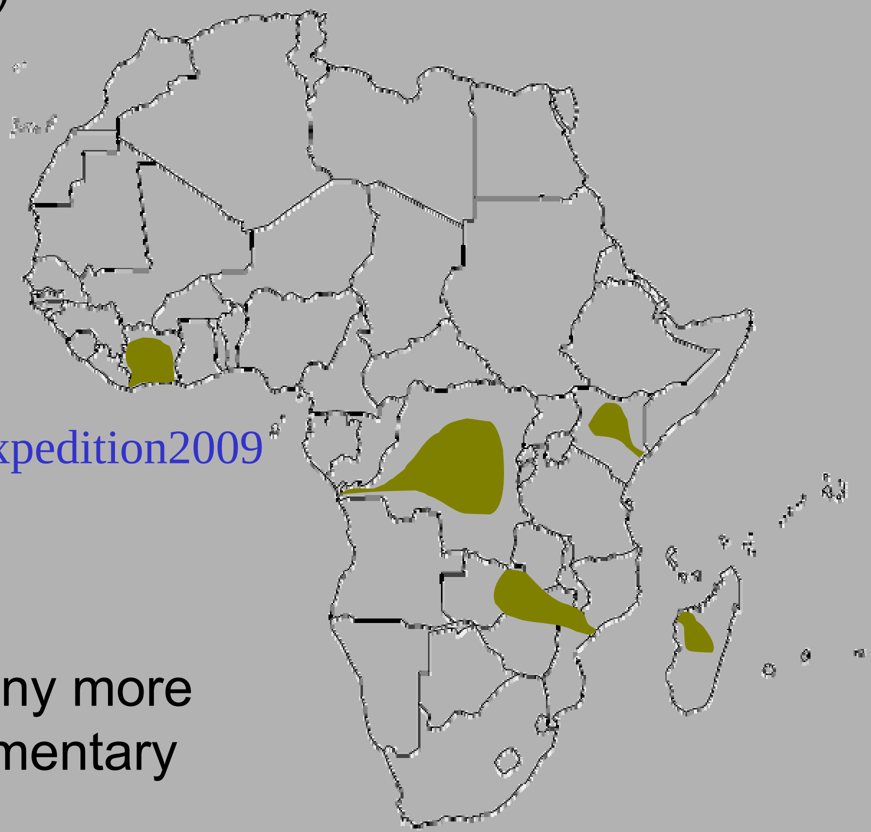


Aquatic biogeochemistry within LSUE ?

Examples of ongoing and future work:

-Carbon cycling in the Tana River basin (Kenya) – FWO (2009-2012)

-Extension towards other African river basins & rift valley lakes (e.g. Zambezi, Betsiboka, Ivory Coast) – ERC (2010-2014)



-Congo river:
currently pre-expedition (2009)
http://www.africamuseum.be/research/congo-expedition2009
Larger campaign 2010 (?)
Proposal submitted

Relatively new research direction – many more opportunities to be developed, complementary expertise within LSUE is strong asset.