First assessment of nitrogen deposition budget following the impoundment of a subtropical hydroelectric reservoir (Nam Theun 2, Lao PDR)

M. Adon[1,2], C. Galy-Lacaux[1], D. Serça[1*], P. Guedant[3], A. Vonghamsao[3], W. Rode[3], Y. Meyerfeld[1], F. Guerin[4]

[1]Laboratoire d'Aérologie, UMR 5560, Toulouse, France, [2]Laboratoire de Physique de l'Atmosphère, Abidjan, Côte d'Ivoire, [3]Nam Theun 2 Power Company Limited (NTPC), Water Quality and Biodiversity Dept., Gnommalath, Lao PDR, [4]GET (Geosciences Environnement Toulouse), UMR 5563, Toulouse, France.

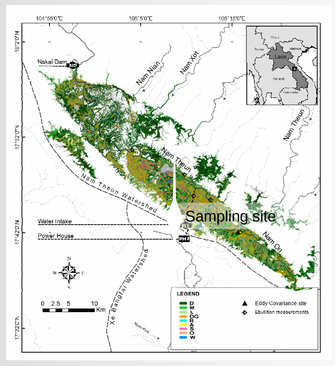
*Contact: dominique.serca@aero.obs-mip.fr

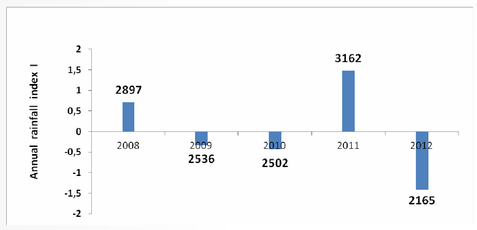
Introduction

Carbon and nitrogen budgets, including greenhouse gas emissions (CO_2, CH_4 & N_2O), have been monitored in the subtropical Nam Theun 2 Reservoir (NT2R, Lao PDR) since impoundment (2009). One of the environmental monitoring objective is to determine the net greenhouse gas footprint of the reservoir. In this context, we present here the first estimation of the atmospheric total (dry + wet) nitrogen deposition budget following a reservoir impoundment based on a two-year monitoring (July 2010-July 2012). Post impoundment total deposition is compared to deposition on the ecosystems pre existing the impoundment (83% forests, 11% rice paddies, 6% water surfaces) assessed assuming unchanged wet deposition fluxes and atmospheric gaseous concentrations.

Sampling

Study site





Annual rainfall index (%): interannual precipitation variability at NT2R (calculated from the deviation of annual precipitation to the mean annual rainfall, 2008-2012 period).

NT2R (17° 59'49''N, 104° 57'08''E), 490km² @ full water operation, Nam Theun River watershed, subtropical climate (wet season: May to October), Lao PDR.

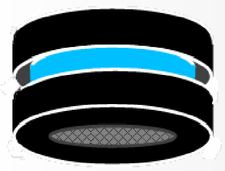
Precipitation chemistry

Year	Ht (mm)	Hc (mm)	EC (%)
2008	2897		
2009	2536		
2010	2502	1602	64
2011	3162	2528	80
2012	1265		

Ht: rainfall, Hc; collected rainfall, EC: collection efficiency

- Wet only rain collection (event)
- Preservation by freezing
- Bi-annual analytical laboratory performance checks (WMO)
- IC analysis

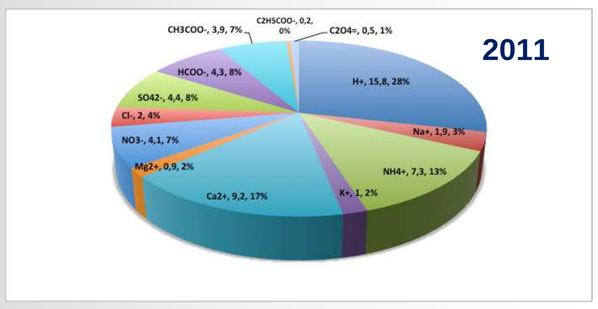
Gas measurements



Atmospheric gas concentrations, monthly sampling, IDAF passive samplers (Adon et al., 2010)

Wet deposition

Major ion species in precipitation

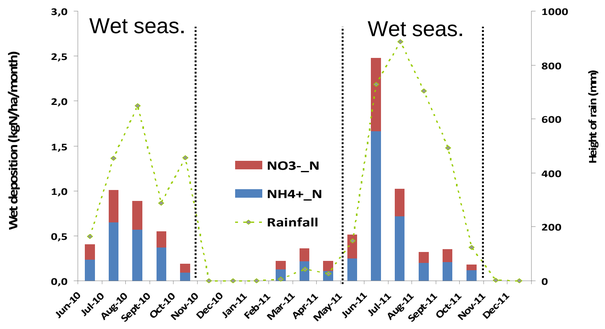


Mean pH = 5.06
52% organic acidity
48% mineral acidity
Mean conductivity Ω = 12µS/cm

Volume-weighted mean conc.

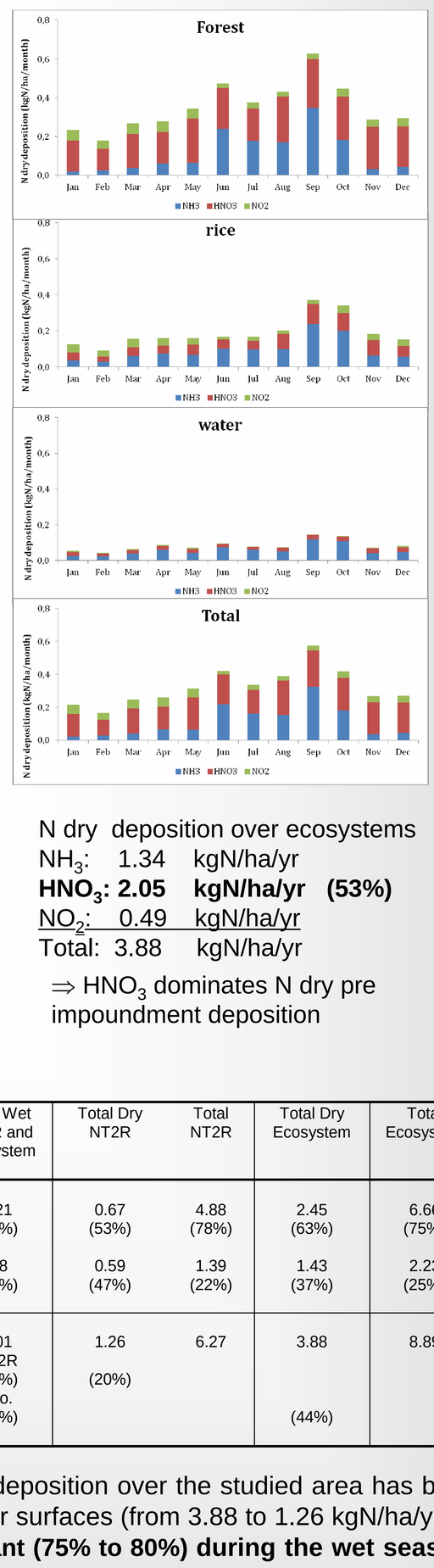
Acidity	Concentration in µeq.l^{-1}	Acidity (%)
Organic acidity		
$HCOO^-$	4,4	25,4
CH_3COO^-	3,9	22,5
$C_2H_5COO^-$	0,2	1,2
$C_2O_4^{2-}$	0,5	2,9
Total	9,0	52,0
Mineral acidity		
NO_3^-	3,9	22,5
SO_4^{2-}	4,4	25,4
Total	8,3	48,0
Total H^+ potential	17,3	
H^+ measured	12,3	

N (NH_4^+, NO_3^-) wet deposition



N wet deposition
NH_4^+: 3.13 kgN/ha/yr (62%)
NO_3^-: 1.88 kgN/ha/yr
Total: 5.01 kgN/ha/yr
⇒ NH_4^+ dominates N wet deposition

N dry deposition - pre impoundment



N dry deposition over ecosystems
NH_3: 1.34 kgN/ha/yr
HNO_3: 2.05 kgN/ha/yr (53%)
NO_2: 0.49 kgN/ha/yr
Total: 3.88 kgN/ha/yr
⇒ HNO_3 dominates N dry pre impoundment deposition

Dry deposition

Deposition velocity V_d

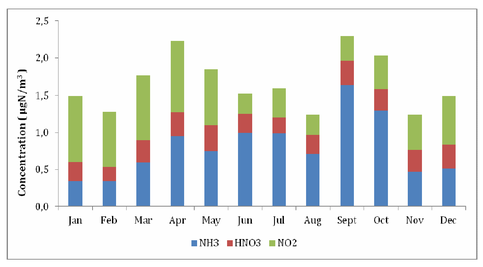
Simulated from Zhang et al. (2003) big-leaf model from two different meteorological inputs:

- Field campaigns over the NT2R water surface
⇒ V_d "Water" for NT2R post impoundment
- ERA-Interim meteorological reanalysis
⇒ V_d "Ecosystems" for pre impoundment

V_d (cm/s)	Water - NT2R(avg)	Ecosystems (avg)
NH_3:	0.26 - 0.49 (0.36)	0.47 – 1.15 (0.70)
HNO_3:	0.28 - 0.52 (0.38)	1.72 – 2.99 (2.35)
NO_2:	0.033-0.036 (0.035)	0.22 – 0.37 (0.28)

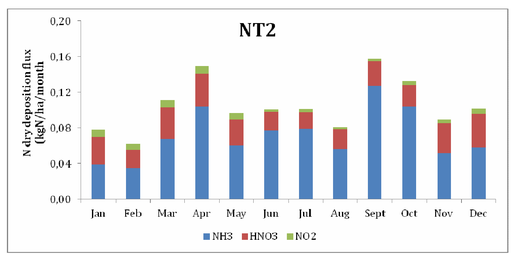
Bidirectional modeling (Zhang et al., 2010) for NH_3 deposition in forest ecosystem

Monthly gas concentrations



Annual concentration
NH_3: 0.83 ± 0.18 µg/m³
HNO_3: 0.28 ± 0.02 µg/m³
NO_2 : 0.57 ± 0.07 µg/m³

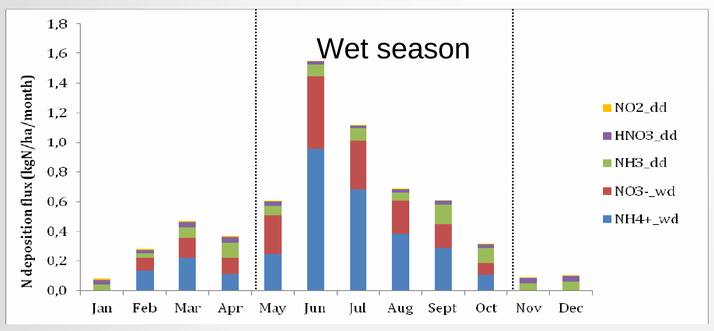
N dry deposition - post impoundment



N dry deposition over NT2R
NH_3: 0.86 kgN/ha/yr (68%)
HNO_3: 0.34 kgN/ha/yr
NO_2: 0.06 kgN/ha/yr
Total: **1.26** kgN/ha/yr
⇒ NH_3 dominates N dry post impoundment deposition

Total (dry + wet) N deposition

NT2R – post impoundment



Average annual total nitrogen deposition flux on:
- NT2R: **6.27 kgN/ha/yr** (80% wet deposition, 78% wet season)
- Pre impoundment ecosystems: **8.89 kgN/ha/yr** (56% wet deposition, 75% wet season).

Deposition onto NT2R is comparable to deposition in the Barnegat Bay, New Jersey (7.46 kgN/ha/yr, Gao et al, 2002), and much lower than deposition found in Lake Sihwa, South Korea (16.6 kgN/ha/yr, Jung et al, 2009). Low deposition in the NT2R might be related to the scarce sources of nitrogen species of anthropogenic origin (besides fires) at the regional scale.

	Total Wet NT2R and Ecosystem	Total Dry NT2R	Total NT2R	Total Dry Ecosystem	Total Ecosystem
Wet season	4.21 (84%)	0.67 (53%)	4.88 (78%)	2.45 (63%)	6.66 (75%)
Dry season	0.8 (16%)	0.59 (47%)	1.39 (22%)	1.43 (37%)	2.23 (25%)
Annual	5.01 NT2R (80%) Eco. (56%)	1.26 (20%)	6.27	3.88 (44%)	8.89

Conclusion

Average annual total (dry + wet) nitrogen deposition flux decreased from 8.89 to 6.27 kgN/ha/yr after impoundment of the NT2R. Total N deposition over the studied area has been **reduced by almost 30%** due to the strong reduction of deposition velocities and subsequent dry deposition fluxes from ecosystems to water surfaces (from 3.88 to 1.26 kgN/ha/yr, or an **increase of wet deposition from a proportion to 56% to 80%**). In both pre and post impoundment conditions, **deposition is dominant (75% to 80%) during the wet season**. Dissolved organic nitrogen (DON) and particulate nitrogen (pNH_4^+ and pNO_3^-) should be added to get a complete picture, results from this study need to be considered as the lower estimate value for the total atmospheric N deposition. N budget at the NT2R, including N_2O emissions, will account for this change on the deposition fluxes at the watershed scale.