AFRIVAL Project (African River Basins)
http://ees.kuleuven.be/project/afrival/
EGU General Assembly 2014, Vienna

KATHOLIEKE UNIVERSITEIT LEUVEN

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Université de Liège

Wetlands influencing river biogeochemistry: the case study of the Zambezi and the Kafue Rivers

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2nd International Conference "Water Resources and Wetlands"
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Introduction: AFRIVAL project (2009-2014)

AFRIVAL – 'African river basin: catchment scale carbon fluxes and transformation" (http://ees.kuleuven.be/project/afrival/)

- joint European Research Council Starting Grant project hosted at the ***Department of Earth & Environmental Sciences (K.U. Leuven, Belgium)*** and the ***Chemical Oceanography Unit (Université de Liège, Belgium)***

- 5-year funding to explore the **role of African rivers in carbon cycling**

- Fieldwork within AFRIVAL has taking place in:
  - •Kenya: *Tana & Sabaki Rivers*
  - •Niger: *Niger River*
  - •Gabon: *Ogooué River*
  - •Madagascar: *Bestiboka and Rianila Rivers*
  - •DRC Congo & Central African Republic: *Congo River Basin*
  - •Zambia & Mozambique: ***Zambezi River Basin***

Tana River

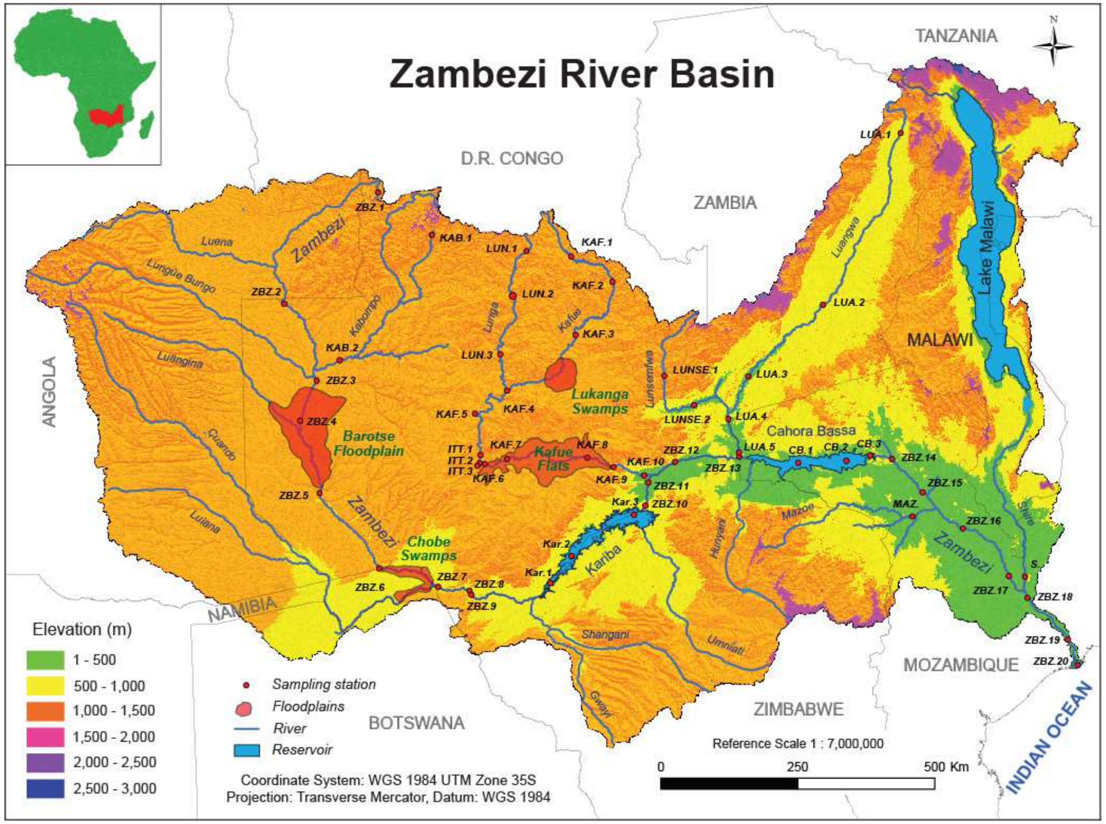
Ogooué River

Niger River

Study site: the Zambezi River

<u>The Zambezi River – general characteristics</u>

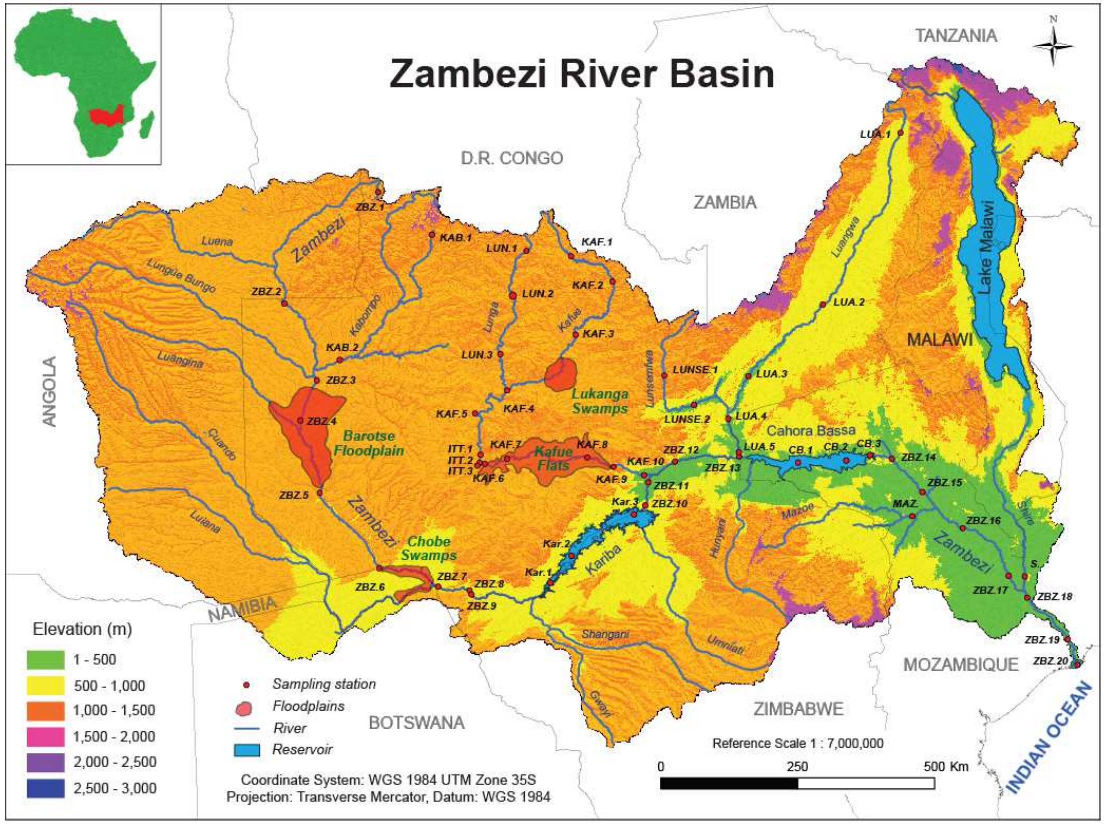
- **4^{th} largest** in Africa and the largest flowing in to the Indian Ocean (from Africa)
- Total length: > **3000 km**; Drainage basin: ~ **1.4×10^6 km^2** (shared by 8 countries)
- Average annual discharge at Zambezi Delta: **3800-4130 m^3 s^{-1}**
- 2 large reservoirs: **Kariba** (5580 km^2; 180 km^3), and **Cahora Bassa** (2670 km^2; 52 km^3)
- 2 major wetlands: **Barotse Floodplains** (7700 km^2), and **Chobe Swamps** (1500 km^2)

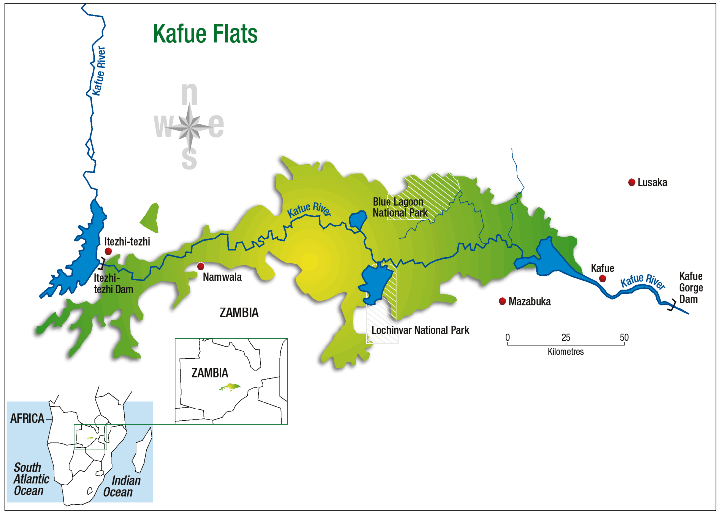


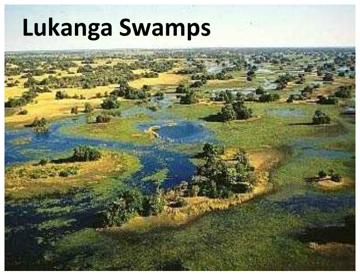
Study site: the Kafue River

The Kafue River – general characteristics

- Main tributary of the Zambezi River (entirely within Zambia)
- Total length: > **1500 km**; Drainage basin: ~ **156,000 km^2**
- Average annual discharge at the confluence with Zambezi: **370 m^3 s^{-1}**
- 2 reservoirs: **Itezhi Tehzi** (365 km^2; 5.5 km^3), and **Kafue Gorge** (13 km^2; 0.8 km^3)
- Major wetlands: **Lukanga Swamps** (2100 km^2), and **Kafue Flats** (6500 km^2)

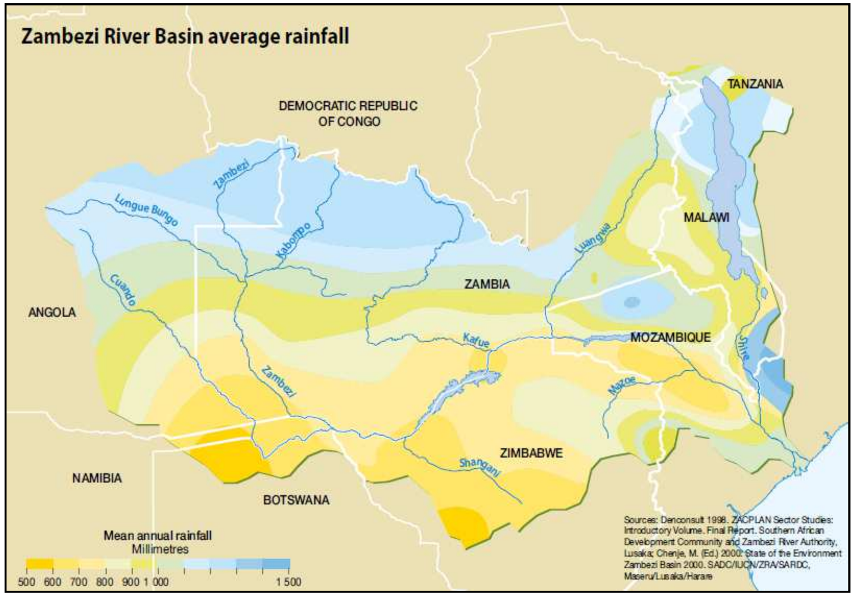


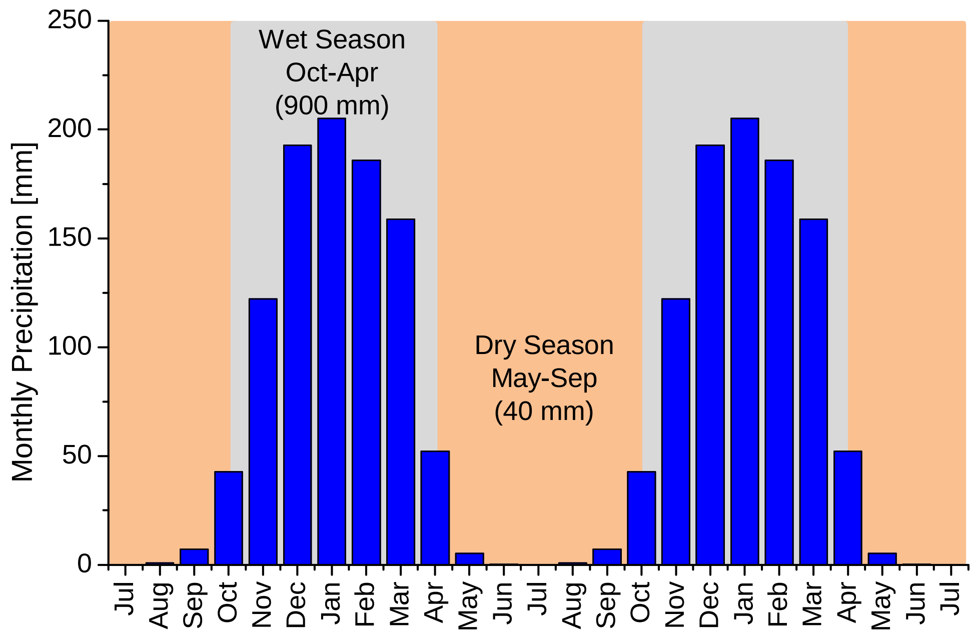




General characteristics: Climate & Rainfall

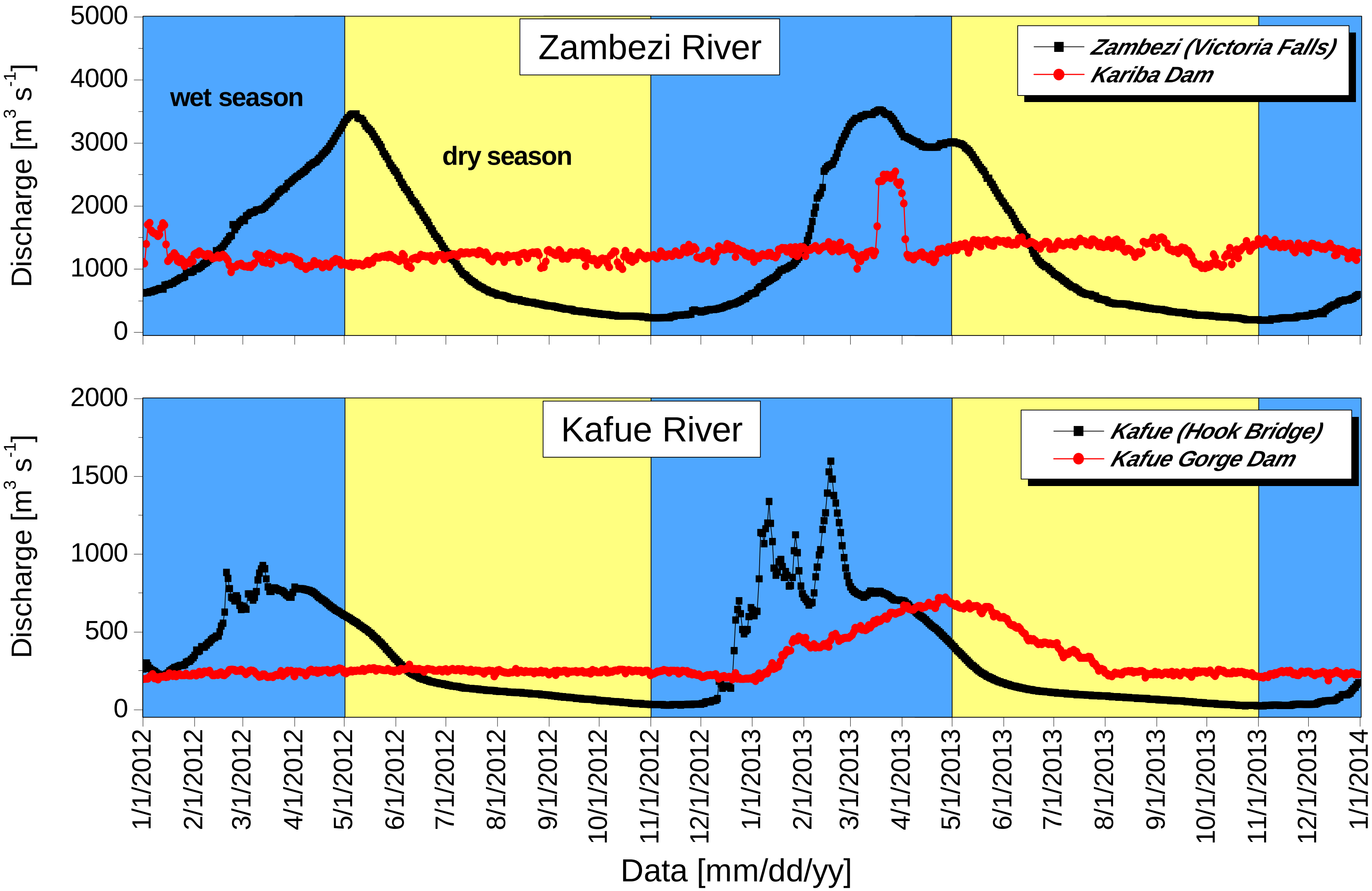
- Climate is classified as ***humid subtropical*** or ***tropical wet and dry***
- Annual rainfall ***varies with latitude***: ***1400 mm*** in N to ***400-500 mm*** in S (mean average rainfall for entire basin: ***940 mm***)
- **Two seasons**:
  1. ***Wet season*** (Oct/Nov – Apr) corresponding to summer, with 95% of annual rainfall (***900 mm***)
  2. ***Dry season*** (May – Sep/Oct), corresponding to winter, with 5% of annual rainfall (***40 mm***).





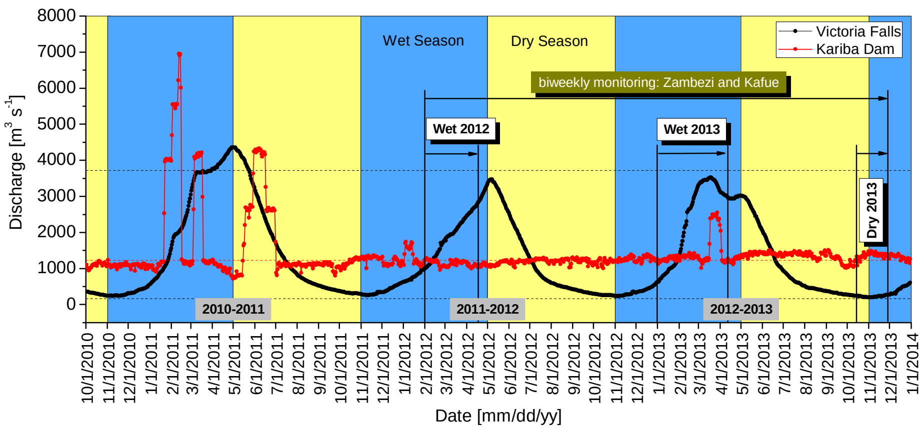
General characteristics: Hydrological cycle

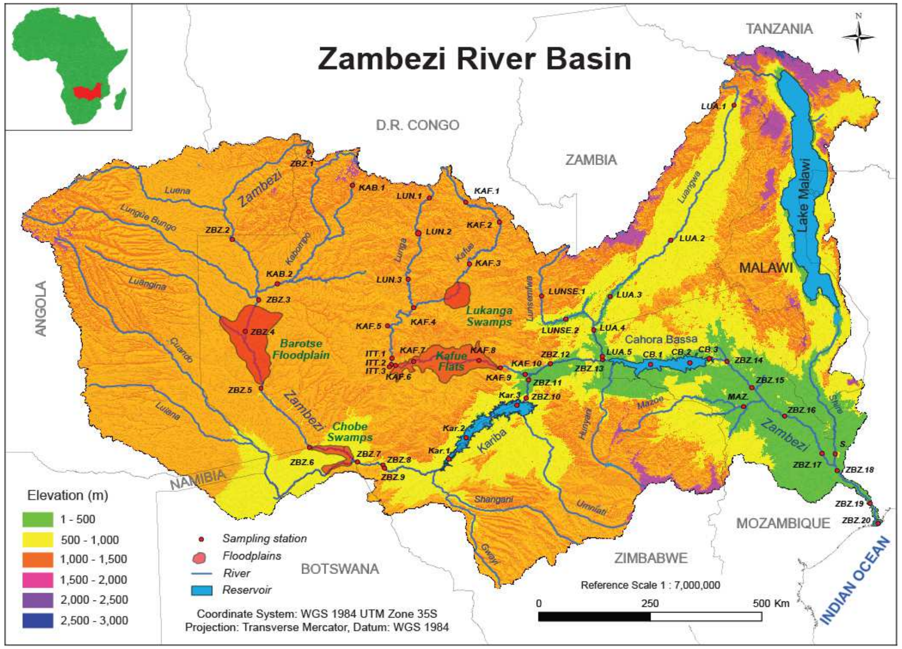
- Driven by seasonality in rainfall patterns resulting in a bimodal distribution with a ***single main peak flood*** (max. Q: Apr/May) and min. flow in Oct/Nov



Methods: Sampling strategy

- **3 sampling campaigns**: ***Wet*** (Feb-Apr) **2012**, ***Wet*** (Jan-Apr) **2013**, ***Dry*** (Oct-Dec) **2013**
- **56** sampling sites: ***26 along Zambezi (Kariba & CB Res.)***, ***13 along the Kafue (ITT Res.)***, and 17 on different tributaries












Methods: Measured parameters

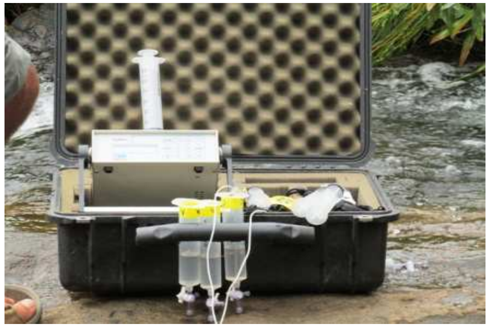
- Physico-chemical: **pH**, **O_2**, t°, conductivity, Total Alkalinity
- Total Suspended Matter (**TSM**) and sediment characterization
- Concentration and stable isotope ($\delta^{13}C$) composition of **POC, DOC,** DIC,
- Aquatic metabolism: Bacterial respiration and primary production
- GHG (***CO_2, CH_4,*** *N_2O*) concentrations and fluxes
- Radiocarbon isotopes dating ($\Delta^{14}C_{POC}$ and $\Delta^{14}C_{DOC}$)



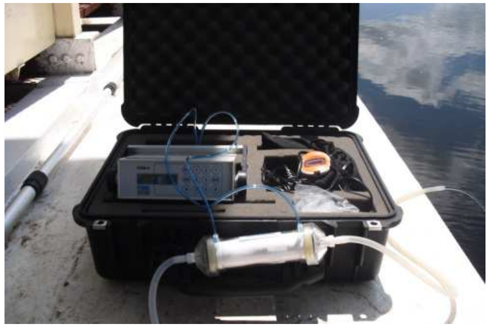


<u>In-situ CO_2 measurements</u>

Headspace Technique



Membrane Equilibrator



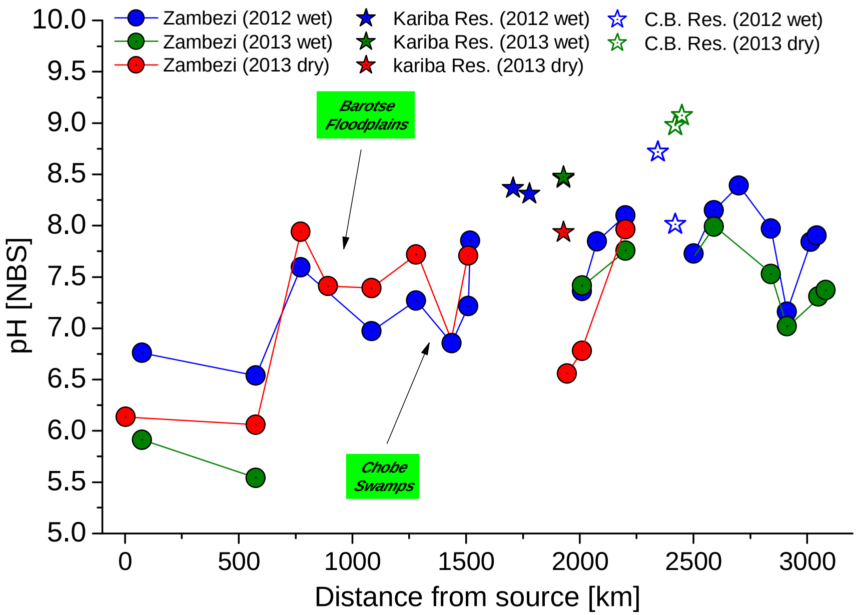
Floating chamber



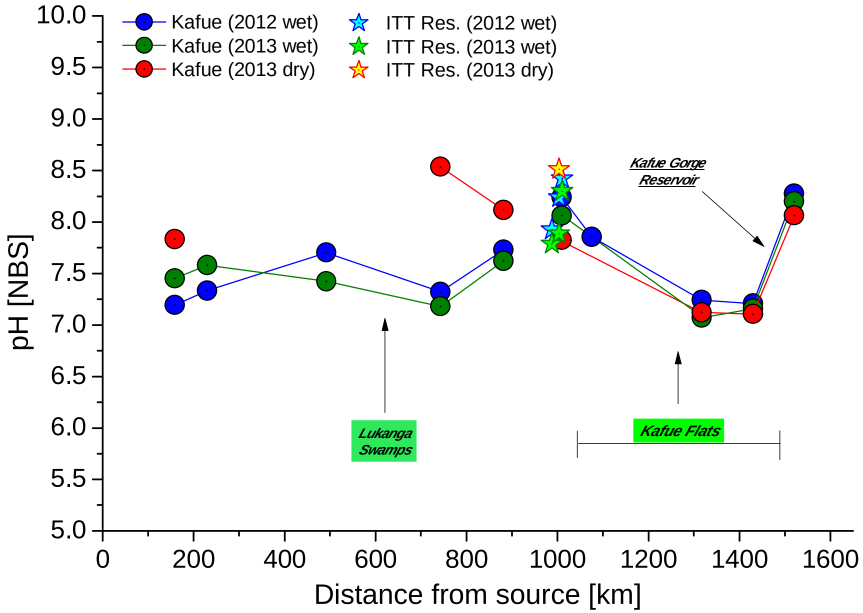


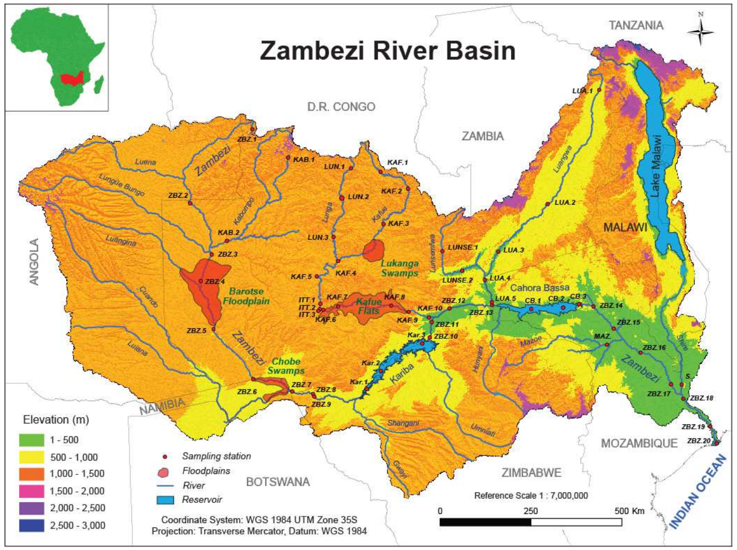
Results: pH spatio-temporal variability

Zambezi River



Kafue River

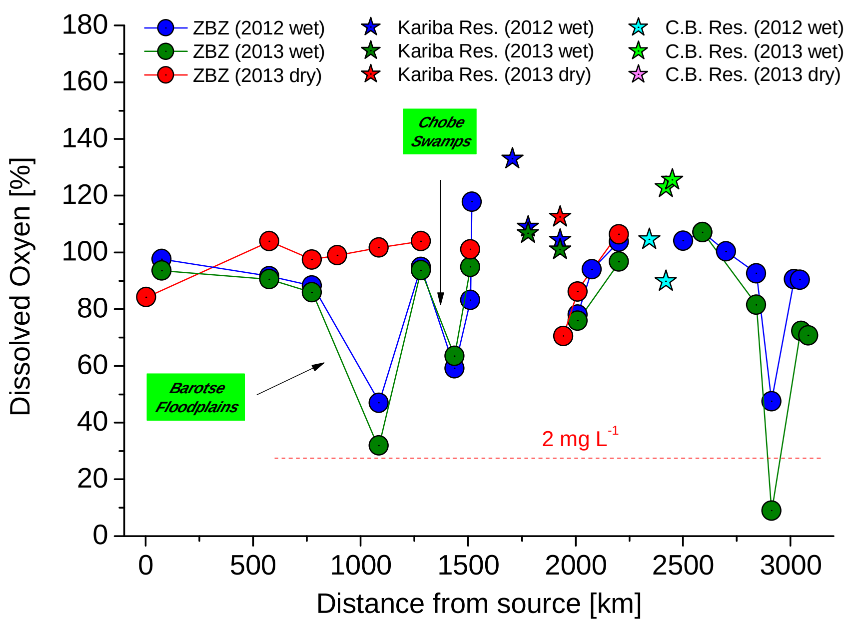




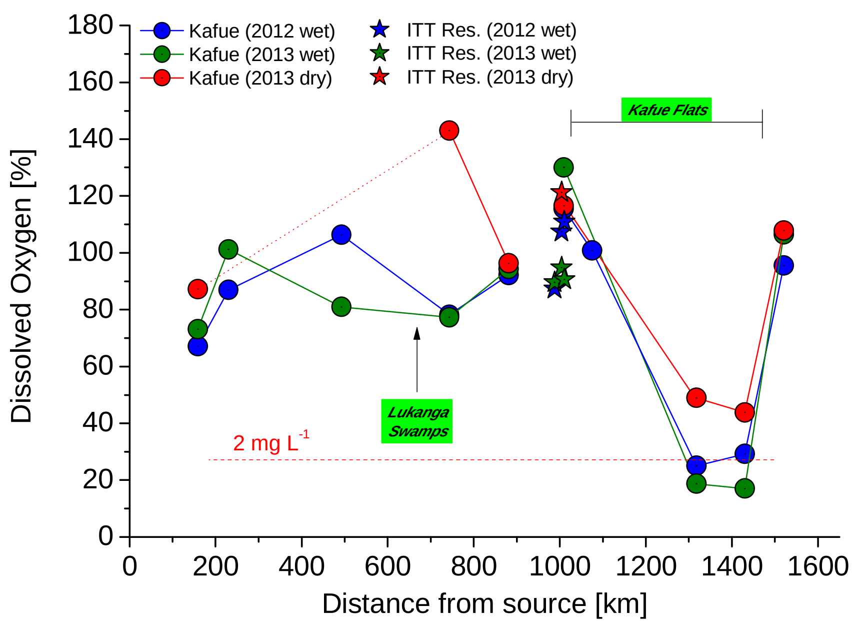
pH decreases (more acidic) in-, and downstream **wetlands**

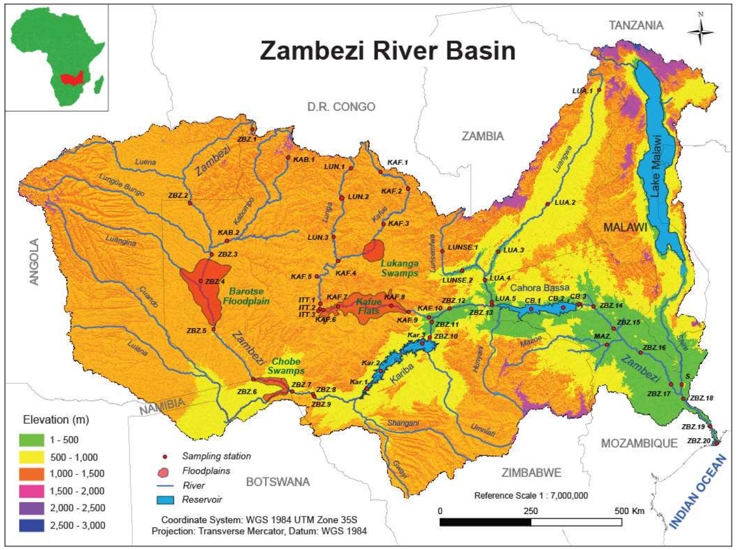
Results: DO spatio-temporal variability

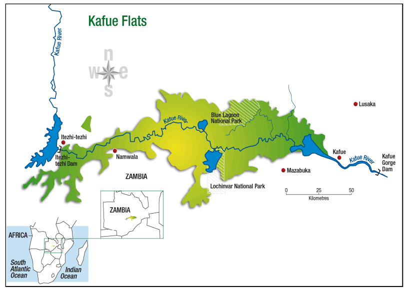
Zambezi River



Kafue River



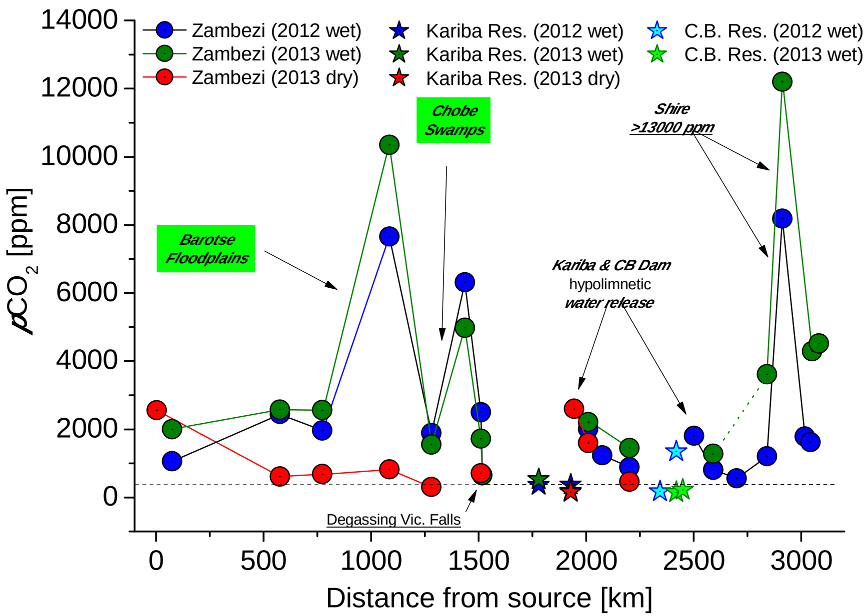




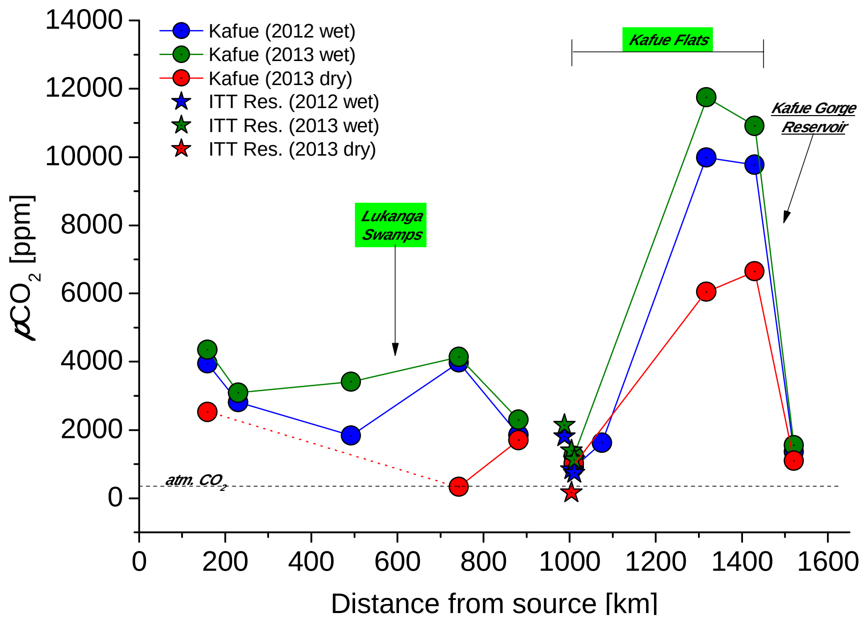
Significant **DO decrease** in-, and downstream **wetlands** (below **2 mg L^{-1}**)

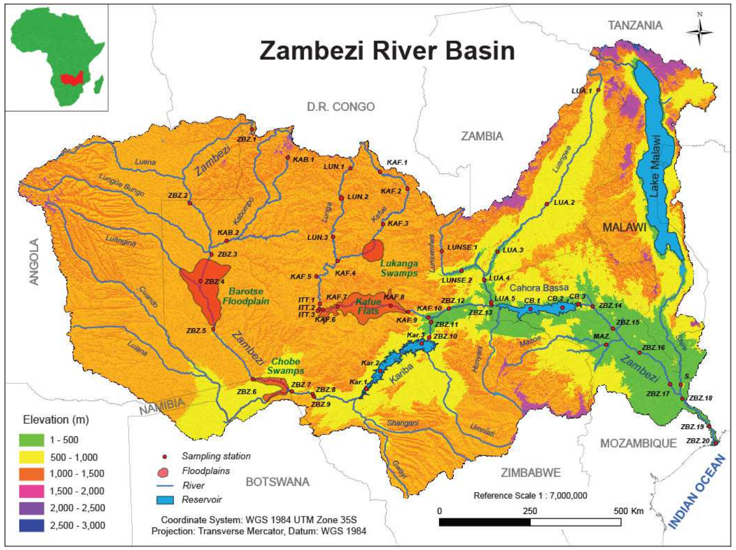
Results: CO_2 spatio-temporal dynamics

Zambezi River



Kafue River

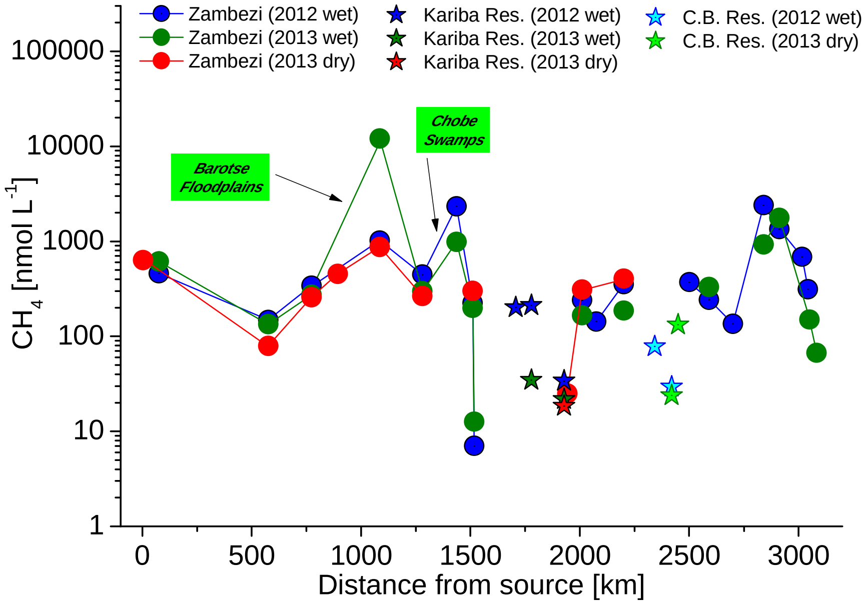




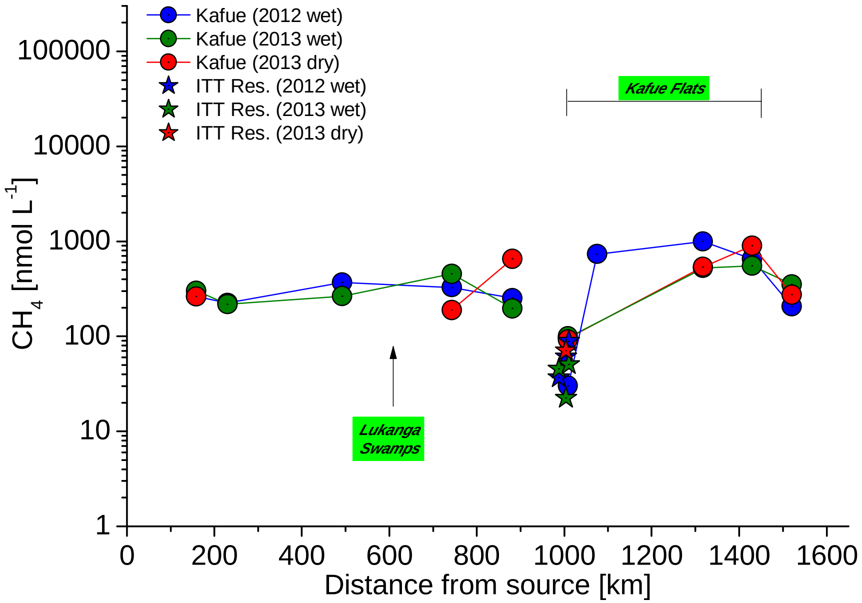
Substantial **increase** in **CO_2** in-, and downstream **wetlands**

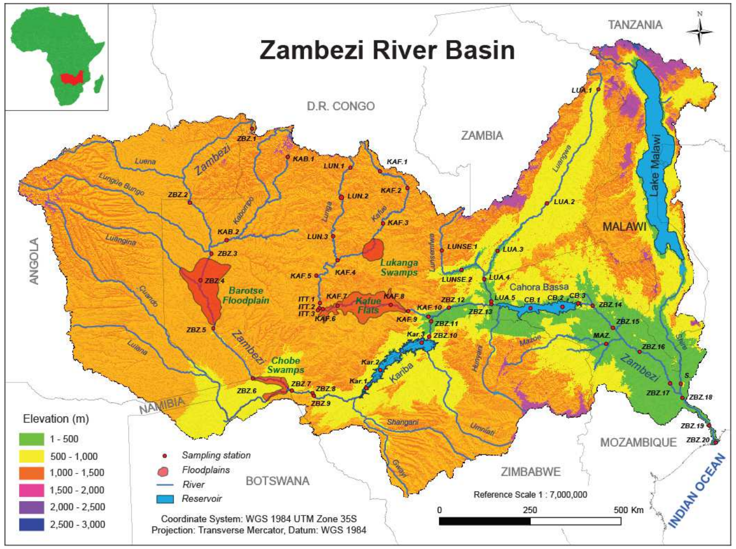
Results: CH_4 spatio-temporal dynamics

Zambezi River



Kafue River

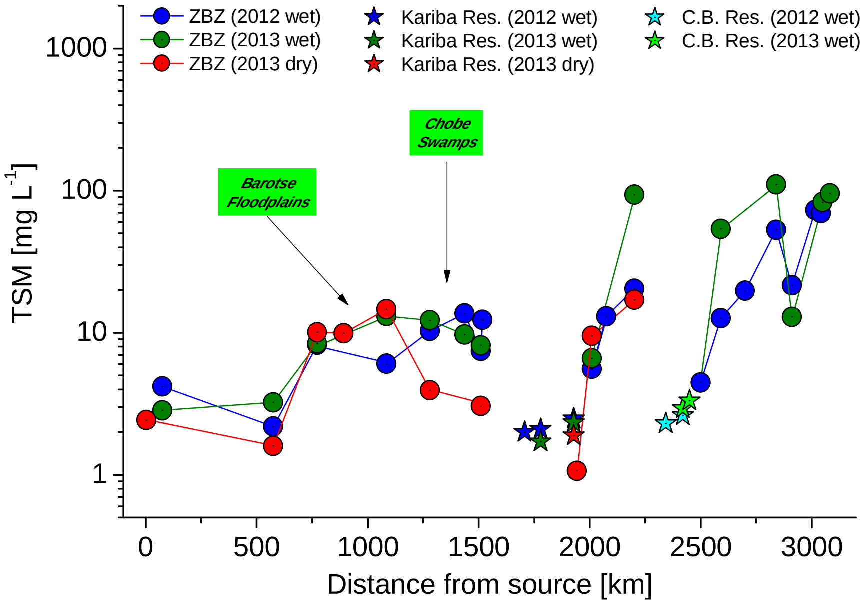




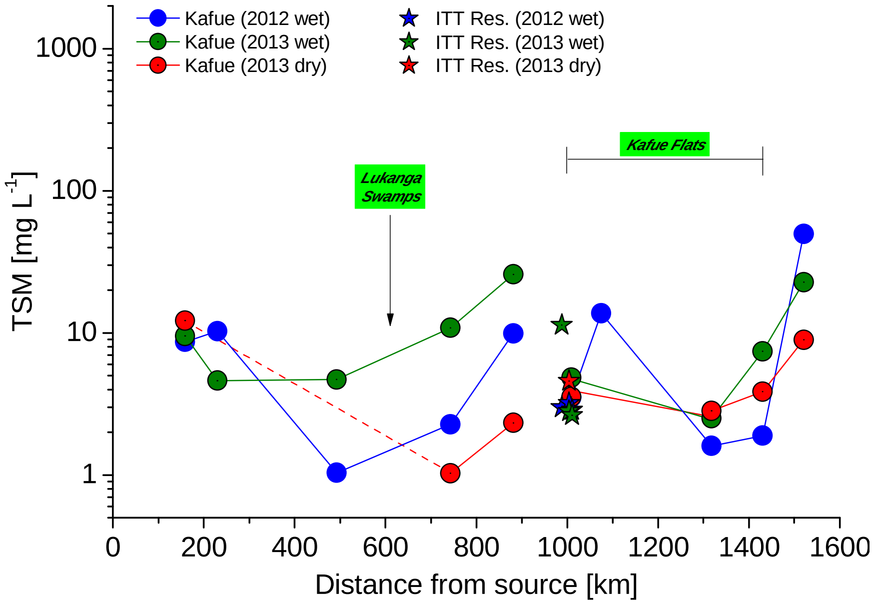
CH_4 increases substantially in-, and downstream **wetlands**

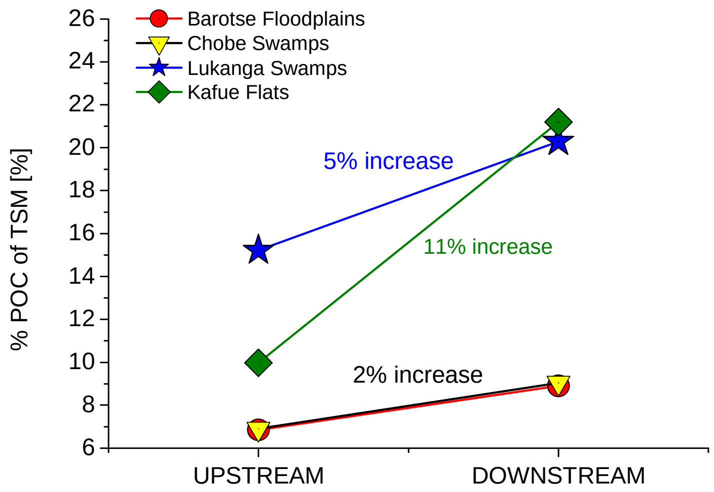
Results: TSM & POC spatio-temporal variability

Zambezi River



Kafue River

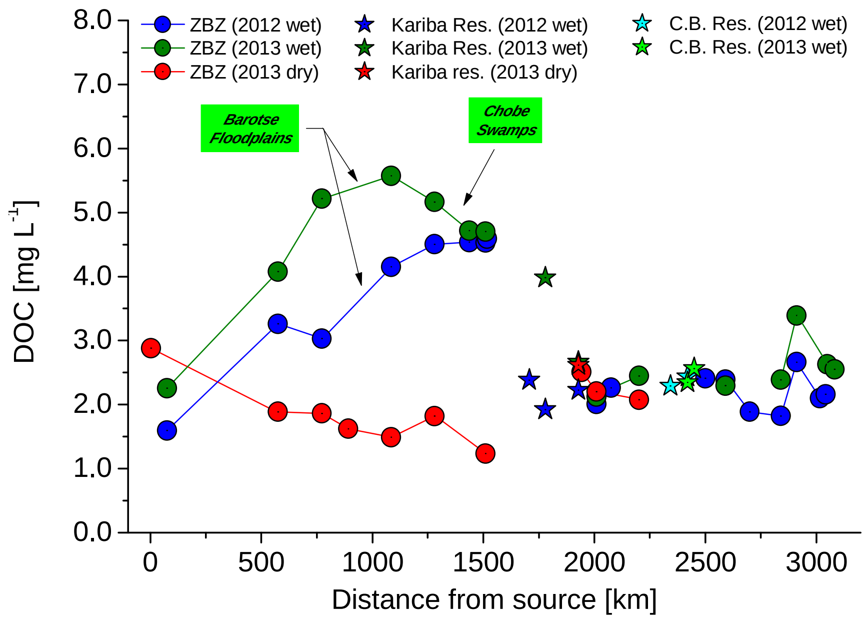




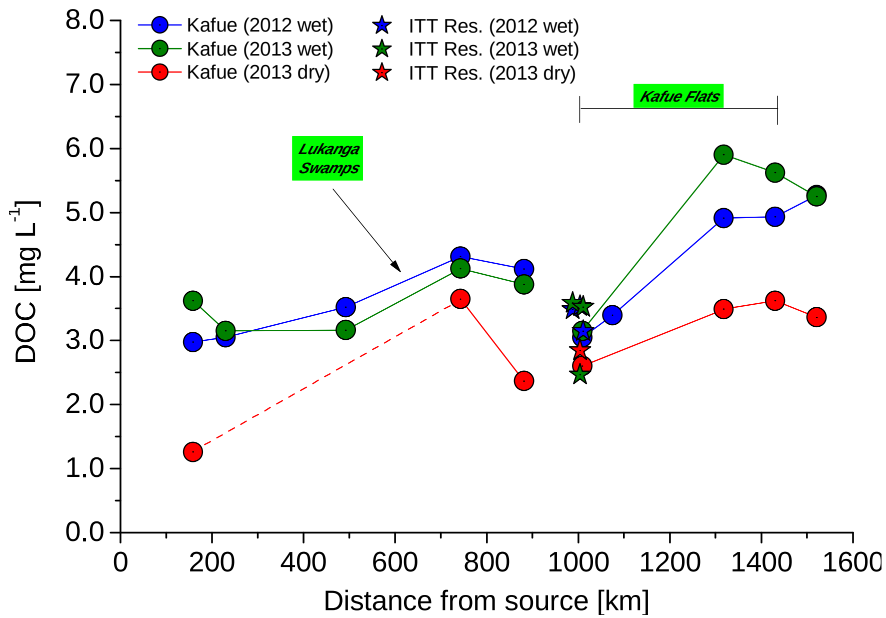
- No clear TSM trend
- Notable **increase** in the relative contribution of **POC** to the **TSM** in-, and downstream **wetlands**

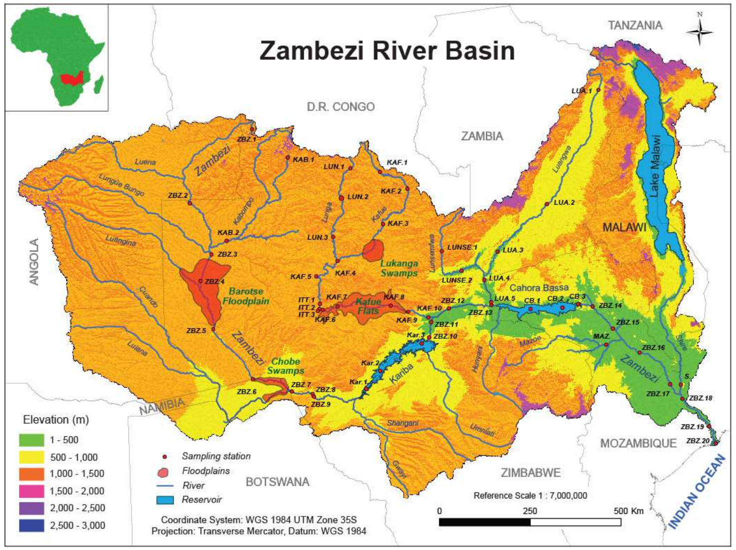
Results: DOC spatio-temporal variability

Zambezi River



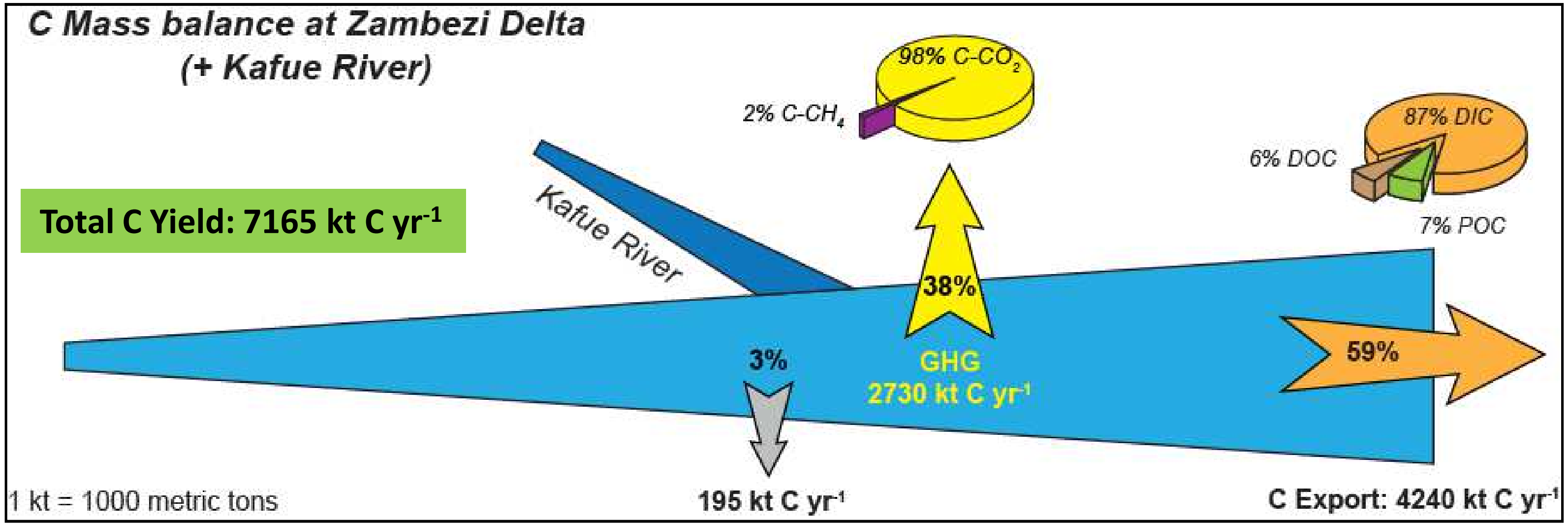
Kafue River

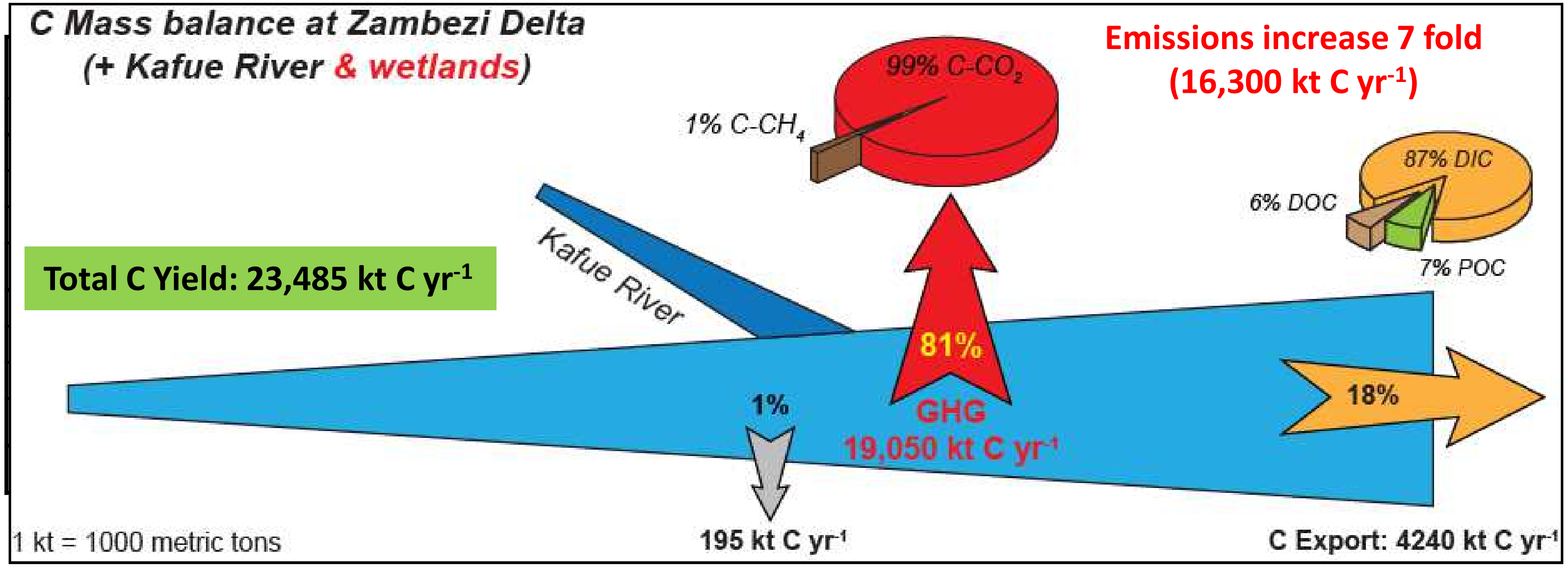




DOC increases in-, and downstream **wetlands**

Results: Carbon Budget





Concluding remarks

- Wetlands/floodplains have large **influence on river biogeochemisty**:
  - **Decreasing** the ***pH*** and ***Dissolved Oxygen*** concentrations
  - **Increasing** the ***Temperature*** and ***Evaporation***
  - **Increasing** CO_2 and CH_4, ***DOC*** and ***POC*** concentrations

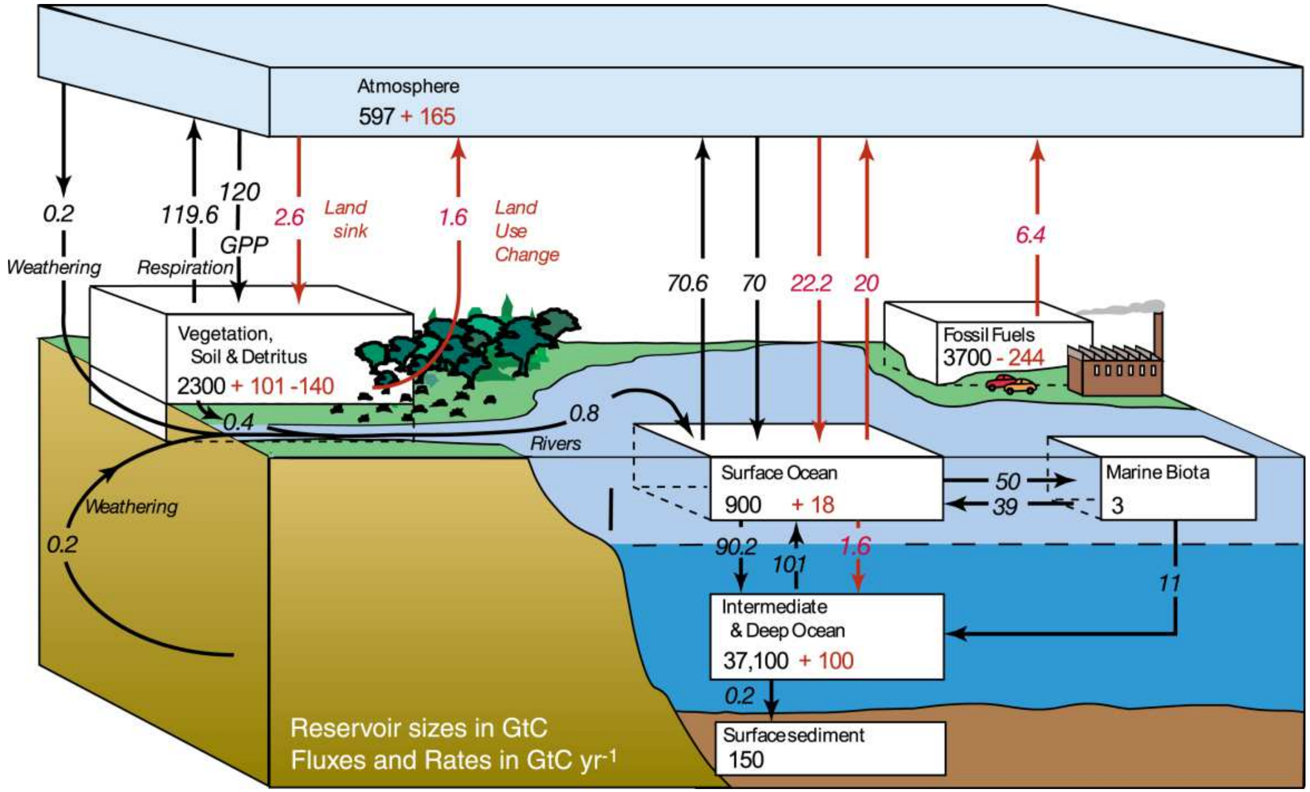
- Highly productive ecosystems, **wetlands are essential elements of carbon cycle,** capable of **shifting significantly the balance** between **Emissions, Storage and Transport** components of **carbon budgets.**

- **Further research** (more quantitative data) are **needed** to better constrain the role of **wetlands** in both **regional and global C budgets,** which so far has been **largely overlooked.**


Thank you for your attention!
“Pirates of the Zambezi”

Introduction: Inland waters in global C cycle

The global carbon cycle



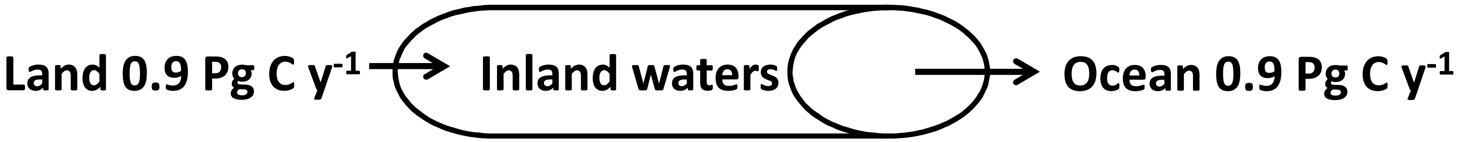
Major carbon reservoirs

- Atmosphere
- Biosphere
- Ocean

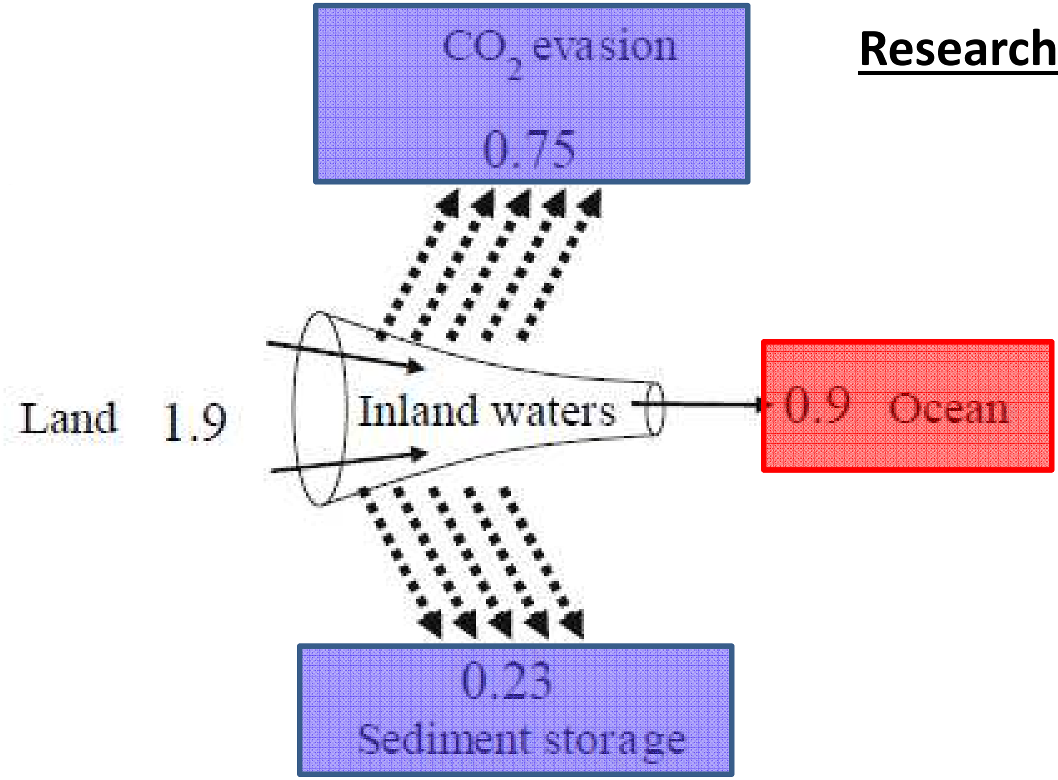
Global C budget studies are mostly limited to the three major carbon reservoirs with little or no focus on inland waters

Introduction: Inland waters in global C cycle

Historical perception



River are passive “pipes” transporting to oceans terrestrial carbon



Research on inland waters suggest that:

- **beside Transport**
- **Emitting**
- **Storing**

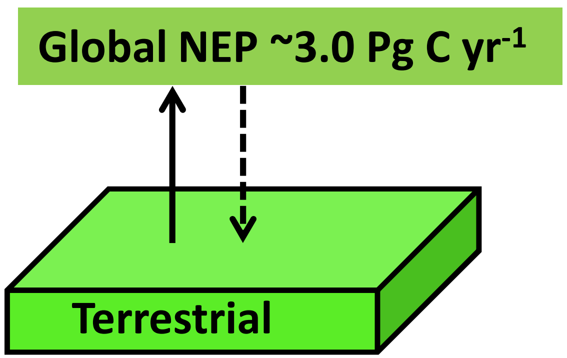
(Cole et al., 2007. Plumbing the global carbon cycle: integrating inland waters into the terrestrial carbon budget. Ecosystems 10, 172–185)

Introduction: Inland waters in global C cycle

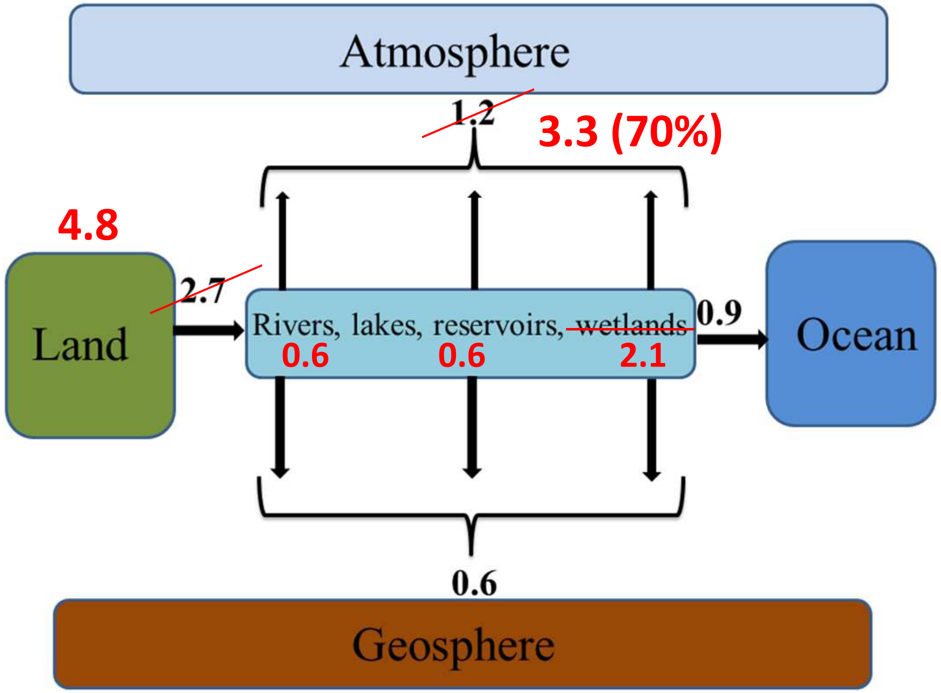
More recent research

*(**Aufdenkampe et al., 2011**. Rivers key to coupling biogeochemical cycles between land, oceans and atmosphere. Front. Ecol. Environ. 9, 53–60)* ***based on Batin el al., 2009***

Canadell & Raupach, 2008



(NEP = GPP + total ER)



Freshwater systems function as biogeochemical "hot spots"

Overlooked importance of wetlands

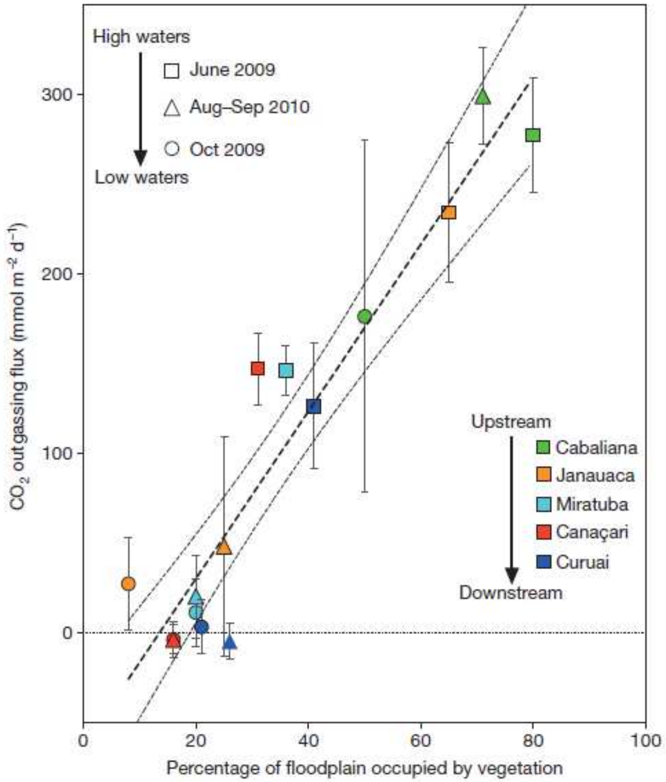
LETTER

doi:10.1038/nature12797

Amazon River carbon dioxide outgassing fuelled by wetlands

Gwenaël Abril[1,2], Jean-Michel Martinez[2], L. Felipe Artigas[3], Patricia Moreira-Turcq[2], Marc F. Benedetti[4], Luciana Vidal[5], Tarik Meziane[6], Jung-Hyun Kim[7], Marcelo C. Bernardes[8], Nicolas Savoye[1], Jonathan Deborde[1], Edivaldo Lima Souza[9], Patrick Albéric[10], Marcelo F. Landim de Souza[11] & Fabio Roland[5]

"Flooded forests and floating macrophytes provide, through litterfall and submerged root respiration, a total of ***305±120 Tg C yr***$^{-1}$ *of atmospheric carbon to the waters"…."not significantly different from the* ***CO_2 outgassing flux of 210±60 Tg C yr***$^{-1}$*. **Central Amazonian waters thus receive at least as much carbon from semi-aquatic plants as they emit to the atmosphere"***



"Three-quarters of the world's flooded land consists of temporary wetlands, but the contribution of these productive ecosystems to the inland water carbon budget has been largely overlooked".