Distribution and cycling of carbon in the Tana River Basin (Kenya), from headwaters to the Tana River delta.

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Introduction

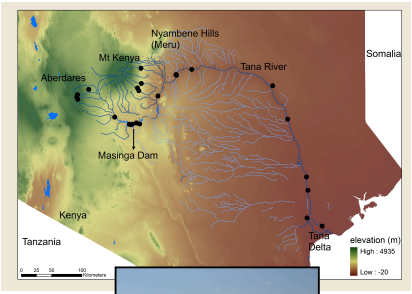
► Data compilations on carbon fluxes in freshwater systems invariably indicate that tropical regions are severely underrepresented. Large-scale studies on carbon processing along the flowpath of river basins have to date been concentrated on a very limited number of systems, e.g., the Orinoco basin, the Ganges-Brahmaputra, and an extensive body of work on the Amazon river basin.

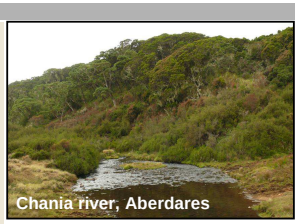
► In this study, we present data on various biogeochemical characteristics of a tropical river basin (Tana river, Kenya), along the flowpath from high-altitude headwater streams in perennial catchment areas, down to the lower river meandering through semi-arid plains. Using a large suite of parameters both on particulate and dissolved carbon pools and nutrients, we present a first basin-wide view on the inputs and processing of carbon in this tropical river basin.

Sites

► The Tana River originates in the vicinity of Mt. Kenya and is the longest river system in Kenya (~1000 km), with a catchment area of ~120,000 km². The three main perennial headwater regions are located in high-altitude regions, i.e. the Aberdare range, the S and E slopes of Mt. Kenya, and the Nyambene Hills. A number of hydroelectric power dams have been constructed along the river since the late 1960's, the largest of which is Masinga Dam. Sampling took place in February 2008, i.e. during dry season (low river flow) conditions. Samples were taken in the three headwater regions, along several points on the main Tana river, and surface water was taken at 4 sites along a transect on the largest of the reservoirs, Masinga Dam.

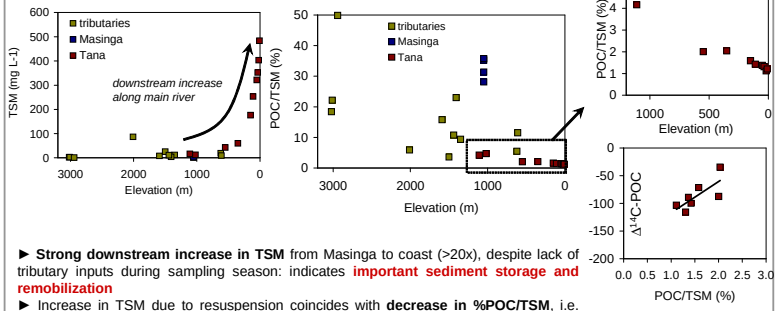
► Surface waters and soil samples at selected locations were analysed for a wide range of physico-chemical and biogeochemical parameters – the focus here is on carbon pools and their stable and radiocarbon isotope composition.





Results & Discussion

Suspended matter and particulate organic carbon



► **Strong downstream increase in TSM** from Masinga to coast (>20x), despite lack of tributary inputs during sampling season: indicates **important sediment storage and remobilization**

► Increase in TSM due to resuspension coincides with **decrease in %POC/TSM**, i.e. indicates **net loss of particle-associated organic carbon during period of within-river storage.**

► Decrease in %POC/TSM accompanied with **decrease in Δ^{14}C-POC**: suggests **preferential loss of recent POC and/or preferential preservation of aged POC**.

Distribution and sources of POC and DOC

► In agreement with the increase in TSM, **POC increases drastically along the main Tana River**, from ~0.6 mg L-1 downstream of Masinga to > 5 mg L^{-1} at the lowest station sampled.

► In contrast, **DOC concentrations along the river continuum are remarkably stable** at 0.98 ± 0.14 mg L-1, leading to a **large shift in DOC/POC ratios** from 1.5 to <0.2 along this transect.

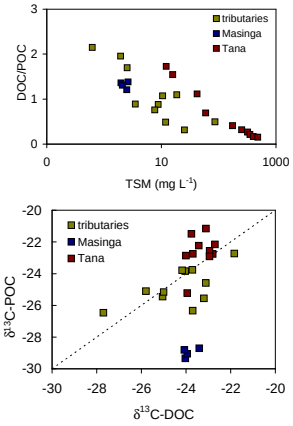
►Variations in DOC/POC are inversely related to TSM (as expected), but relationships are different for tributaries and main Tana River.

► River basin has **mixed C3-C4 vegetation**. At high altitude, C4 plants are restricted to a few tussock-forming species in e.g. the Aberdares, at lower altitudes grasses in savannas are exclusively C4. Soil samples encompass the full range of C3-C4 continuum (-28.5 to -13.2 ‰).

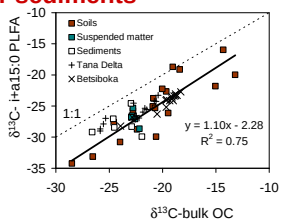
► **δ^{13}C-POC** varied between -26.5 and -22.7 ‰ for tributaries, between -25.2 and -21.2 ‰ along the main Tana river, and **much more negative in Masinga (-29.0 ± 0.3 ‰)** where it reflects dominance of phytoplankton.

► **δ^{13}C-DOC** ranged between -27.7 and -21.8 ‰ in tributaries, within a narrow range of between -24.0 and -22.7 ‰ along the Tana river, and showed **no marked depletion in ^{13}C Masinga Dam** (-23.9 ± 0.3 ‰).

► Thus: **δ^{13}C-DOC and δ^{13}C-POC clearly uncoupled** and showed a relatively weak relationship.



Bacterial carbon sources in suspended matter, soils and river sediments



Despite some scatter, **δ^{13}C of bacterial markers generally follow those of bulk carbon pools** in both soils, TSM and riverine sediment. Consistent also with previous data from coastal mangrove (i.e. C3) sediments with C4 inputs [Ralison et al. *Org. Geochem.* 39: 1649-1658, 2008; and Bouillon et al. *L&O* 52: 46-59].

→ **No clear indication for selective use of C3 or C4 material.**

Effects of Masinga Dam

► Surface waters of Masinga Dam appear **highly productive**, with much **lower pCO_2** (378 ± 57 ppm) compared to the main river, **high $\%O_2$**(111 ± 3 %) **, and low δ^{18}O-O_2** (+19.2 ± 0.2 ‰).

► **POC is dominated by phytoplankton** biomass with low δ^{13}C, while **DOC appears to retain its original δ^{13}C signature,** suggesting high turnover rates of phytoplankton-derived DOC and/or low reactivity of terrestrially-derived DOC.

► Comparison of nutrient concentrations in the main inflow and outflow indicates **a high degree of nutrient retention**: >50% for DIN, >70% for DIP, and ~40% for Si.

► δ^{13}C-POC below Masinga relatively low (-25.2 ‰) reflecting a contribution of reservoir phytoplankton. This signature rapidly shifts to -21.5 ‰, with a concurrent loss of POC (%POC/TSM from 4.6 to 2.0 %), consistent with rapid selective loss of ^{13}C-depleted phytoplankton.

Methane

► CH_4 concentrations in headwater streams ranged typically between 25 and 92 nM, except for Muringato river (314 nM) and Mutundu river (410 nM), above atmospheric equilibrium (<3 nM) .

► In the main Tana river, CH_4 concentrations were relatively high upstream of Masinga Dam (505 nM) but lower below the reservoir (372 nM), and **much lower in surface waters of the reservoir (51 ± 7 nM), suggesting a high CH_4 oxidation activity** (or emission to the atmosphere) despite the likeliness of CH_4 production in its anoxic waters.

► Along the middle and lower course, CH_4 concentrations ranged between 54 and 387 nM, with the highest concentration observed in the Tana Delta.

pCO_2 and indicators of aquatic metabolism

► Although no direct metabolism rate measurements were made during this survey, several patterns suggest that **in-stream primary production can be significant, even in the highly turbid waters of the middle and lower Tana River:**

• **$\%O_2$** was high in all tributaries, Masinga Dam, and typically only slightly undersaturated along most of the Tana River.

• **δ^{18}O-O_2 was consistently lower than the value expected for equilibrium with atmospheric O_2** (i.e., +24.2‰), and ranged between +19.0 and +23.0 ‰ – suggesting contributions by isotopically light O_2 from photosynthesis (δ^{18}O between -5.6 and -2.7 ‰).

• **pCO_2** in headwater streams ranged between 110 and 1020 ppm, and ranged between 500 and 660 ppm along most of the main Tana River, except for high pCO_2 at the outflow of Masinga and towards the tidal delta (3570 and 1540 ppm, resp.). While generally oversaturated, these pCO_2 levels are in the lower range of those observed in other tropical river systems.

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