Dear Editor,

Thank you for your efforts and those of the reviewers in evaluating and handling our manuscript bg-2021-69, “Partitioning carbon sources in a tropical watershed (Nyong River, Cameroon) between wetlands and terrestrial ecosystems – Do CO_2 emissions from tropical rivers offset the terrestrial carbon sink?”.

We will revise the manuscript according to our responses to the reviewers’ comments, which responses are detailed below. Briefly, in the revised manuscript, we will add new figures showing relationships between river discharge and the different variables (see figures below in this document). Also, we will add a new figure describing the Mengong catchment (first order catchment) with characteristics soil profiles and longitudinal sections in the Mengong catchment, which helps better interpret the biogeochemical characteristics of waters drained from the land and wetlands. In addition, as suggested by the reviewer#1, our study design might not allow the estimation of the drainage of non-flooded forest groundwater and wetlands in streams order higher than 1 (we only can assume that a similar drainage occurs in all stream orders but it is too speculative). Therefore, we estimate the riverine carbon budget (drainage of non-flooded forest groundwater and wetland, carbon evasion and carbon export) in the Mengong catchment only. However, we will also keep the estimations of carbon evasion and carbon export at the catchment scale as described in the previous version of our manuscript but we will not estimate the partitioning of carbon coming from the drainage of non-flooded forest groundwater and wetland at the catchment scale. In addition, as suggested by two referees, we will estimate the two latter fluxes (carbon evasion and export) from monthly concentrations instead of yearly averages. This allows us to discuss the monthly variability of carbon evasion together with water surface area and gas exchange rates (see figures below in this document). Accordingly, we changed the title of our revised manuscript that now reads: " Partitioning carbon sources between wetland and non-flooded forest in a first-order catchment in the tropics - Implications for understanding carbon cycling in the whole watershed ".

Best regards / Moustapha Moussa, Loris Deirmendjian & Frédéric Guérin

With the exception of the "GENERAL ANSWER", all of our response text sections begin with "Answer" immediately following reviewer comments.

GENERAL ANSWER

Here, we respond more generally to questions about the hydrological functioning of the Mengong catchment (first-order catchment), the carbon mass balance calculation in the Mengong catchment, and the spatial and temporal variations of the different carbon forms as a function of river discharge at the whole catchment scale, which have been asked by the three reviewers.

Hydrological functioning of the Mengong catchment (first order stream)

- **Study site**

The landform of the Mengong catchment is composed of convexo-concave relief that ranges from 669 m at the river outlet to 703 m at the top of the hill, separated by flat wetland (Figure 1). The wetland covers 20% of the watershed (Figure 1). Semi-deciduous rainforest (*Sterculiaceae-Ulmaceae*) covers most of the rounded hills, and cultivated food crops, including tubers, manioc, peanuts, palm trees, and plantain, cover the remaining. In addition, farmers practiced cultivation without external chemicals. The vegetation cover on the hillsides limits the erosion. Most of the wetland vegetation comprise semi-aquatic plants of the Araceae family and tree populations of Gilbertiodendron deweverei *(Caesalpiniaceae*) and Raffia monbuttorum (raffia palm trees).

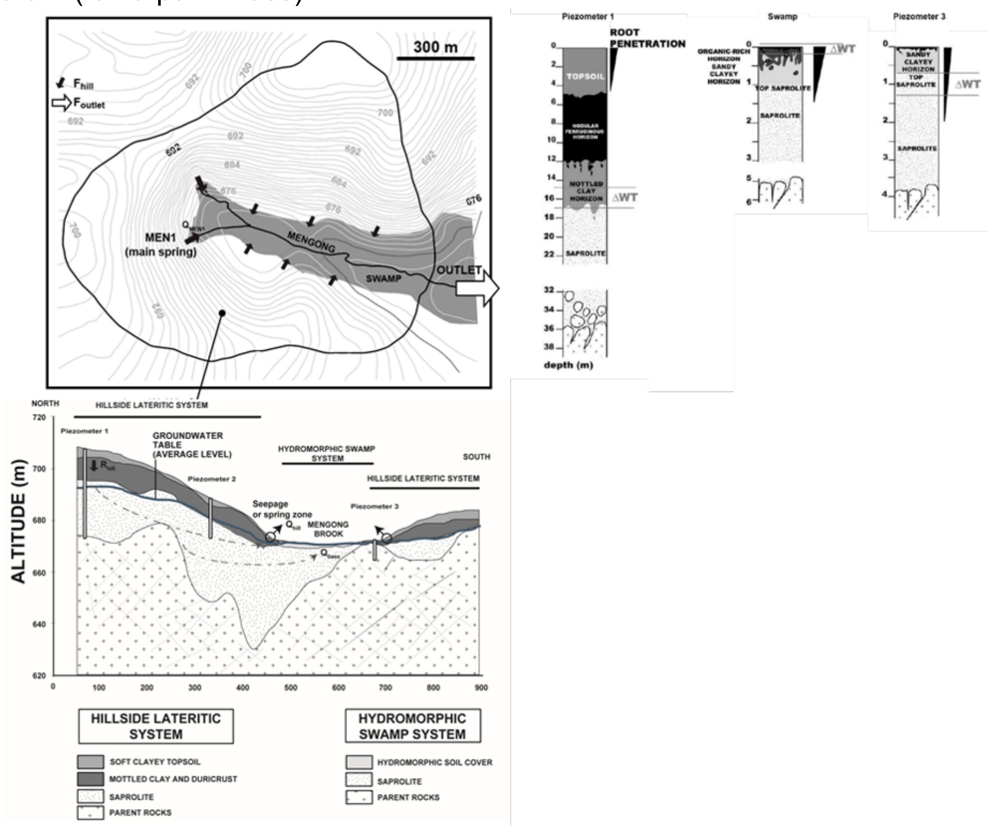


Figure 1 showing the hydrological functioning of the Mengong catchment (first order catchment) and the soil characteristics in piezometer 1, 3 and the wetland (water table level in piezometer 1 and 2 is presented in the figure 2). Adapted from Braun et al. (2005, 2012)

- **Soil cover on the hillside and the wetland**

The hillside soil cover is composed of a thick saprolite and complex polygenetic lateritic soil that consists of three main horizons, namely from the bottom to the top, the mottled clay horizon, the nodular ferruginous horizon, and the soft clayey topsoil (Braun et al. 2005; Figure 1). The thickness and distribution of these soil layers depend on the topographic position. The soil cover is 15 m thick at the top of the north hill (piezometer 1); the depth however, decreases progressively towards the flat wetland. The roots of the hillside vegetation are essentially concentrated in this topsoil horizon, which has a depth of 5 to 6 m at the top of the hill (at piezometer 1) and has a depth of 3 to 4 m (at piezometer 2) at the mid-slope (Braun et al. 2005; Figure 1).

In the wetland, a dark-brown organic-rich sandy material with a thickness ranging from 0.1 to 1 m tops the hydromorphic soil. In the poorly drained zone, the organic horizon is composed of a thick mat of dead and living roots and tubers of the wetland vegetation. In the well-drained wetland zones, towards the outlet, the sandy clayey material is covered by a much thinner organic accumulation (Braun et al. 2005). All year long, the wetland is flooded and fed by groundwater seepage coming from the hillside (Maréchal et al. 2013). We adopt, here, the common definition of wetlands as habitats with continuous, seasonal, or periodic standing water or saturated soils (Mitsch et al., 2012)

- **Hydrology of the Mengong catchment**

The groundwater floods the fractured bedrock, the entire saprolite, and partly the mottled clay horizon (Braun et al. 2005; Figure 1). In the piezometer 1 profile, the maximum water table fluctuation is about 3 m (Figure 2). A part of the groundwater draining the hillside emerges at springs (Q_{hill} in the figure below, it is where we sampled carbon parameters and that we called "forest groundwater" in the previous version of the manuscript, but based on reviewer#1 comment, we call now the groundwater that emerges at springs "non-flooded forest groundwater") in the watershed head and at specific seepage points (Q_{base}) all around the hill-side/wetland boundaries and then is conveyed to the stream. Indeed, the groundwater that emerges at specific seepage points and springs is conveyed over the ground with negligible interaction with the wetland (Maréchal et al. 2013)

According to observations made in the Mengong catchment during most of the rainfall events by Maréchal et al. (2013), it is assumed that the overland flow can be neglected on the forested hillside (i.e., no surface runoff is occurring). The water budget of the hillside/bedrock aquifer system, as shown in the figure above, is therefore:

$R_{hill} = Q_{hill} + Q_{base}$ *(Eq. 1)*

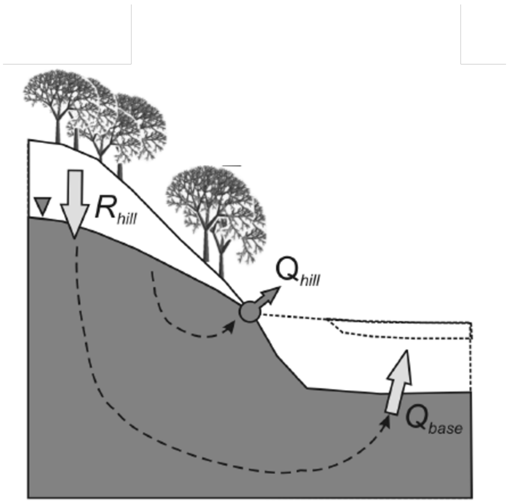
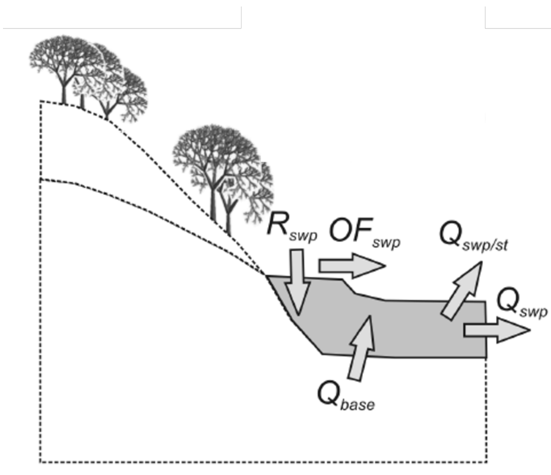


Figure showing the hydrological functioning of the hillside system, adapted from Maréchal et al. (2013)

In the wetland aquifer system as shown in the Figure below, inflows are the recharge rate on the wetland ground surface (R_{swp}) and the baseflow from the bedrock aquifer (Q_{base}), while outflows are groundwater flow below the weir at the outlet (Q_{swp}) and exchanged with the stream ($Q_{swp/st}$). The groundwater budget of the wetland is therefore:

$Q_{base} + R_{swp} = Q_{swp} + Q_{swp/st}$ *(Eq. 2)*

Figure showing the hydrological functioning of the wetland system, adapted from Maréchal et al. (2013)



The total streamflow at the outlet of the Mengong catchment as shown in the Figure below is the sum of the contributions of the bedrock aquifer, the exchange flow between the wetland and the stream and the overland flow on the wetland surface as the following:

$Q_{st} = Q_{hill} + Q_{swp/st} + OF_{swp}$ *(Eq. 3)*

where OF_{swp} is the overland flow on the surface of the wetland

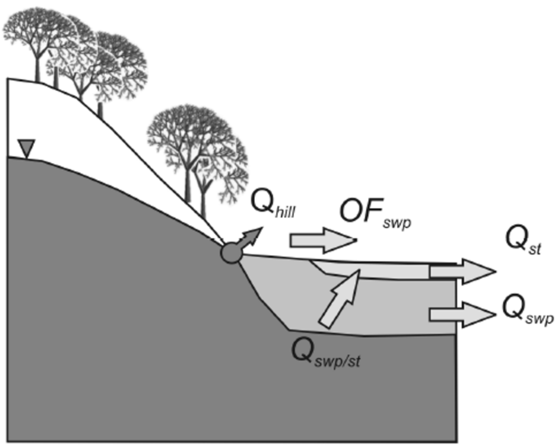


Figure showing the hydrological functioning of the Mengong catchment system, adapted from Maréchal et al. (2013)

- **Carbon inputs to the first order stream of the Mengong catchment**

At the Mengong catchment scale; as described above there are two sources fueling the stream with carbon: non-flooded forest groundwater and the wetland.

According to equations 1, 2 and 3, at the scale of the Mengong catchment, we can estimate the quantity of dissolved carbon leached to the stream from non-flooded forest groundwater (F_{GW}) as the following:

$F_{GW} = R_{hill} * [C]$ *(Eq. 4)*

Where [C] is the concentration of DOC or DIC in the non-flooded forest groundwater.

We can estimate the quantity of dissolved carbon leached to the stream from the wetland (F_{SW}) as the following:

$F_{SW} = (OF_{swp} + Q_{swp/st}) * [C]$ *(Eq. 5)*

Where [C] is the concentration of DOC or DIC in the top soil solution of the wetland.

In addition, as mentioned in the previous version of our manuscript and above in this document: in the Mengong catchment the surface runoff is negligible and there is no particulate C in non-flooded forest groundwater. Therefore, the POC at the Mengong outlet should originates mostly from the erosion of the wetland and can be estimated as the following:

$F_{SW} = Q_{st} [POC]_{outlet}$ *(Eq. 6)*

Where [POC] is the concentration of POC at the outlet of the Mengong catchment.

- **Carbon outputs from the stream of the Mengong catchment**

At the Mengong catchment scale, there are two outputs of riverine carbon: carbon evasion from the stream to the atmosphere and carbon exported by the stream at the outlet of the catchment:

Based on equation 3, the quantity of carbon exported at the outlet of the catchment can be estimated as the following:

$F_{outlet} = Q_{st} [C]_{outlet}$ *(Eq. 7)*

Where [C] is the concentration of POC, DOC or DIC at the outlet of the Mengong catchment

It has been shown that a large fraction of carbon evasion in headwaters was actually missed by conventional stream sampling because a large fraction of the degassing occurs as hotspots in the vicinity of groundwater resurgences (e.g., Deirmendjian et al., 2018; Johnson et al., 2008). Therefore, we estimated carbon evasion with a hydrological method that calculates the loss of the dissolved CO_2 between non-flooded forest groundwater (or wetland water) and surface water, using CO_2 concentrations and drainage data as the following:

F_{degass} from gw = $([CO_2]_{GW} - [CO_2]_{outlet}) * R_{Hill}$ *(Eq. 8)*

F_{degass} from sw = $([CO_2]_{sw} - [CO_2]_{outlet}) * (OF_{swp} + Q_{swp/st})$ *(Eq. 9)*

$F_{degass} = F_{degass}$ from gw + F_{degass} from sw *(Eq. 10)*

Where F_{degass} is the estimation of carbon evasion at the scale of the Mengong catchment, which is the sum of the stream carbon degassing fed both by the non-flooded groundwater and the wetland

- **C budget at the Mengong catchment scale**

Now, we can estimate the riverine DIC and DOC budgets:

imbalance of the DIC budget in t C yr^{-1} = inputs – outputs

imbalance of the DIC budget in t C yr^{-1} = $F_{sw} + F_{gw}$ + respiration - $F_{degass} - F_{outlet}$

imbalance of the DIC budget in t C yr^{-1} = 1.7 + 6.7 + 0.4 – 6.3 -1.2 = 1.3

DIC inputs and outputs fluxes are not statistically different although they are different by 17%. In the revised manuscript, we will discuss about the imbalance (17%) of the DIC budget at the Mengong catchment scale which can be attributed to a potential overestimation of heterotrophic respiration as it was measured in the dark (preventing potential primary production) and a potential underestimation of CO2 outgassing downstream of the spring due to our sampling strategy.

imbalance of the DOC budget in t C yr^{-1} = inputs – outputs

imbalance of the DOC budget in t C yr^{-1} = F_{sw} + F_{gw} - respiration – F_{outlet}

imbalance of the DOC budget in t C yr^{-1} = 1.7 + 0.2 – 0.4 – 6.4 = -4.7

Thus, the imbalance of the DOC budget is -4.7 t C yr^{-1} (-257%), which shows that a major DOC input flux was not measured. Indeed, Braun et al. (2005) measured during 4 years of field sampling an average DOC concentration in the throughfall of the Mengong catchment in the range 3.6±3.5 mg/L. Applying this number to the average precipitation in 2016 and the catchment surface area, it gives us an input DOC flux from precipitation in the range 4.3±4.1 t C yr-1, which very likely allows closing the DOC budget at the Mengong catchment scale.

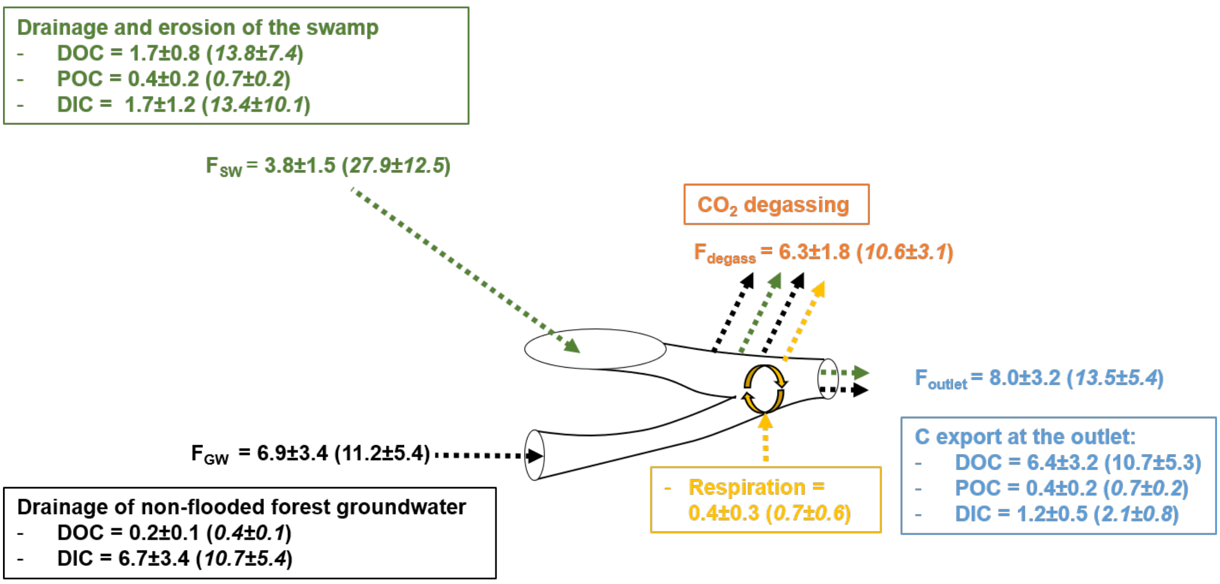


Figure showing the C budget at the Mengong catchment scale in t C yr^{-1}. Number between brackets are in t C km^{-2} yr^{-1}. For the drainage of the wetland, the flux between bracket is weighed by the wetland area (0.12 km²), for the drainage of non-flooded forest groundwater it is weighed by the surface area drained by the hillside (0.48 km²) and for the other fluxes it is related to the catchment surface area (0.6 km²)

In addition, Nkounde et al (2008) estimated the NPP and litterfall (including mature and wetland forests) at the scale of the Mengong catchment at 1 495 and 645 t C yr^{-1}, respectively.

However, POC exported at the outlet of the Mengong catchment is 0.4 t C yr^{-1}, which is ~1 500 times lower than the litterfall. This suggests that most of the litterfall reaches the soil where the litter is degraded and, so contributes to soil respiration and export of IC to groundwater but due to limited surface runoff only a small organic fraction of the litterfall is exported to the stream.

From our revised estimations of the carbon mass balance of the Mengong catchment we show that the drainage of the non-flooded forest groundwater plus the drainage of the wetland represent 0.7% of the NPP of the catchment. About 60% of this carbon exported to the stream is quickly degassed in the vicinity of the water resurgences. If we consider DOC input from the throughfall, the carbon evasion represents 42% of the total C inputs to the stream. The river heterotrophy represents 6.5% of the degassing. Quantitatively, non-flooded forest groundwater exports 1.8 times more carbon than the wetland, however, in terms of quantity weighed by the surface area drained by each system, the wetland exports 2.5 times more carbon than the non-flooded forest groundwater.

- **Carbon variations in groundwater**

In the revised manuscript, we will add a new figure (see figure 2 below) showing hydrological and carbon parameters in the groundwater and first order stream of the Mengong catchment system (first order catchment). This revised figure 2 shows the temporal variations of rainfall in the Mengong catchment, water-table level and soil surface in piezometer 1 and 2 (see the figure 1) in the Mengong catchment, river discharge at the outlet of the Mengong catchment, and pCO2, TA and ancillary parameters (O2, pH, conductivity) in non-flooded forest groundwater (measured at the spring, see the figure 1 and the description of the figure 1) and stream of the Mengong catchment. In addition, TSM, POC content of the TSM, POC and DOC are shown for stream water at the river outlet. In the revised version of our manuscript, we now separated (but not binned) the hydrograph into the 4 seasons that occurs in Cameroon (LDS as long dry season, SRS as short rainy season SDS as short dry season, LRS as long rainy season), which we believe is more representative of the hydrological functioning of the Nyong catchment.

Groundwater pCO2 started to increase at the end of the SRS, concomitantly with the rise of the water table level (Figure 2). It is likely due because the water table has risen closer to the root's penetration zone (Figure 1) where soil respiration is more intense, as observed in other catchments (e.g., Amundson 1998 and references therein). The percolation of rainwater through the soil pores that facilitate the transport and the dissolution of soil CO_2 to the underlying groundwater, a process discussed in the previous version of our manuscript, appears now not significant because we did not observe any increase of groundwater pCO_2 when the rainfall was strong at the beginning of the SRS.

In Amazonia, Johnson et al. (2008) showed at the onset of the dry season the pCO_2 increased in the deep soil due to increases soil water uptake and roots activity. Subsequently, pCO_2 in the deep soil decreased later in the dry season because of drainage and diffusional losses. They showed that pCO_2 in groundwater followed this trend, with increase in concentrations at the onset of the dry season and decreasing after the peak of the dry season. In groundwater of the Mengong catchment, we observed a similar trend as groundwater pCO_2 was higher during the SDS and then was diluted as water table increase during the following LRS. Also, groundwater pCO_2 peaked during the LDS but less significantly than during the SDS, likely because the water table during the LDS is deeper than roots penetration zone (Figure 1). Johnson et al. (2008) showed indeed that groundwater springs in Amazonia closely reflect the CO_2 concentration in the deep soil.

At the beginning of the SRS, when the water table level is the deepest, groundwater O2 is maximal, showing that atmospheric air invaded the groundwater during this period, which is consistent with d13C-DIC values close to the atmospheric equilibrium of -10‰ measured during this period by Nkounde et al. (2020).

Groundwater TA is low and almost stable during the year but peaked during the LRS a couple of days before the peak of the water table and decrease when the water table dropped. This might be due to the fact that the groundwater has risen close to the mottled clay horizon which is more weatherable than the saprolite horizon (Braun et al., 2005). In addition, the weathering is controlled by soil humidity, which is higher during the LRS (Braun et al., 2005, 2012).

Groundwater is free of DOC (below the detection limit) all year long, as mentioned in our manuscript. In a temperate catchment with podzols in which DOC is well complexed and stabilized with iron oxides in the topsoil, Deirmendjian et al (2018) showed that the water saturation of the top soil was necessary to allow the leaching of DOC in the groundwater and therefore to generate high concentrations of DOC in the groundwater. As shown by Braun et al. (2005) in the Mengong catchment, DOC in the upper soil is also well complexed and stabilized with the iron-rich mottled clay horizon and the water table never reaches the surface horizons of the soil where DOC is high (Braun et al. 2005), very likely explaining the fact that the non-flooded groundwater in the Mengong catchment is free of DOC.

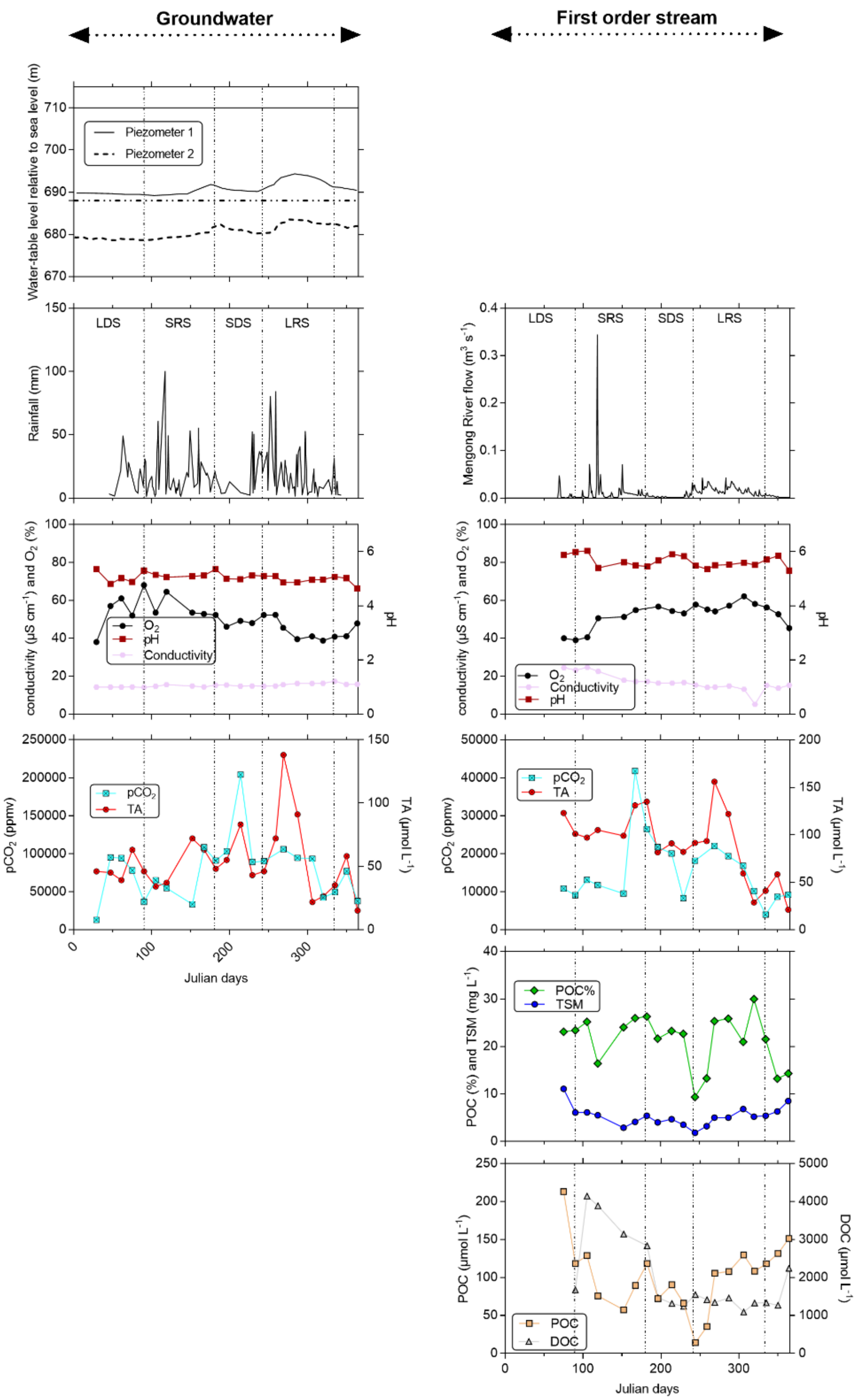

Groundwater
First order stream
Water-table level relative to sea level (m)
Piezometer 1
Piezometer 2
Rainfall (mm)
Mengong River flow ($m^3 s^{-1}$)
LDS
SRS
SDS
LRS
conductivity ($\mu S cm^{-1}$) and O_2 (%)
pH
O_2
Conductivity
pCO_2 (ppmv)
TA ($\mu mol L^{-1}$)
pCO_2
TA
POC (%) and TSM (mg L^{-1})
POC%
TSM
POC ($\mu mol L^{-1}$)
DOC ($\mu mol L^{-1}$)
POC
DOC
Julian days

Figure 2

- **Carbon variations in surface waters**

Overall, in first order stream, there are weak relationships between carbon concentrations and river discharge (Figure 2), suggesting that the hydrological and biogeochemical responses as a function of the rainfall events in this first order basin is faster than our sampling frequency. Indeed, some authors have shown that rainfall events in the Mengong catchment induced a rapid hydrological response at the river outlet (Maréchal et al., 2013; Nkoundou, 2008). Nevertheless, in the first order stream, DOC quickly increased at the beginning of the SRS when the river flow started to increase (Figures 2). In other stream orders, similar DOC increase occurs at the beginning of the SRS but with a slight delay of about a couple of weeks in comparison to the first order stream (Figures 2, 3). After this peak, DOC decreased to reach minimum values during the SDS, and then DOC concentration is stable until the first rains come again in the SRS. Nkounde et al. (2008) described the translatory flow (piston effect) that occurs at the beginning of the SRS in the Mengong catchment. This mechanism assumes that water received by the hillside induce a pressure wave downstream, causing immediate exfiltration at the bottom of the slope (i.e., in the wetland). This means that wetland DOC is quickly flushed during the first rains and DOC comes from the subsurface horizons of the wetland. The lag time between the peaks of DOC in first and sixth order streams might be due to the time the water needs to flow from upstream to downstream. Subsequently, the DOC decrease is due to dilution with non-flooded forest groundwater with a low DOC content.

POC increased in two steps. A first increase occurred at the end of the SRS whereas a second increase occurred during the LRS (Figures 2-3). During wet seasons (after the translatory flow has occurred) the water table in the wetland rises which causes the leaching of the wetland surface where particulate organic matter has accumulated (Nkoundou et al., 2020). During the dry seasons, POC decreases because wetlands shrink and the connectivity between wetland and surface waters water also decreases (Nkoundou et al., 2020). In addition, a slight POC increase occurs during the LDS (in particular in lower stream orders) (Figures 2, 3). In the surface waters of the Nyong, POC and TSM were negatively correlated ($r = -0.4$, $p<0.001$). During the LDS, the wetlands shrink and thus streams are mainly fed by non-flooded forest groundwater. As a result, POC from wetland might not contribute significantly to the total POC discharge by rivers due to very limited drainage in the wetland during LDS. Therefore, most of the organic load of rivers is of autochthonous origin, due to phytoplankton (e.g., Meybeck 1993), which was suggested by Nkoundou (2008) who measured d13-POC close to the phytoplankton value during the LDS in the Mengong catchment. However, we also believe that the contribution of C4 plants in the wetland/watershed could have also increased the d13C-POC. At the onset of the LRS (August-September), abundant silt and clay fractions of terrigenous origin from erosion of wetlands and river banks become dominant. Concomitantly, primary aquatic production is inhibited by high turbidity, which minimizes the OM content of autochthonous origin (Meybeck, 1982) in favor to allochthonous organic carbon. The low concentrations of POC observed during high water are due to the dilution of the POC by the increasing flows of groundwater in the drains.

The pCO2 in first order stream increased at the end of the SRS and at the beginning of the LRS (Figures 2, 3). As we observed no concomitant increase in groundwater pCO2 at the end of the SRS or at the beginning of the LRS, this suggests that this increase is rather due to the drainage of the wetland than the drainage of non-flooded forest groundwater. Even if we cannot exclude the outflow of CO2 originating from non-flooded forest groundwater, it probably quickly degasses in the vicinity of the springs, and therefore CO2 in stream is more influenced by the wetland which is closer to the stream than the groundwater springs. During dry seasons, pCO2 in surface waters decreases as the connectivity with the wetlands and the stream decreases too. In addition, decreasing river flow and turbidity during dry seasons allows aquatic primary production.

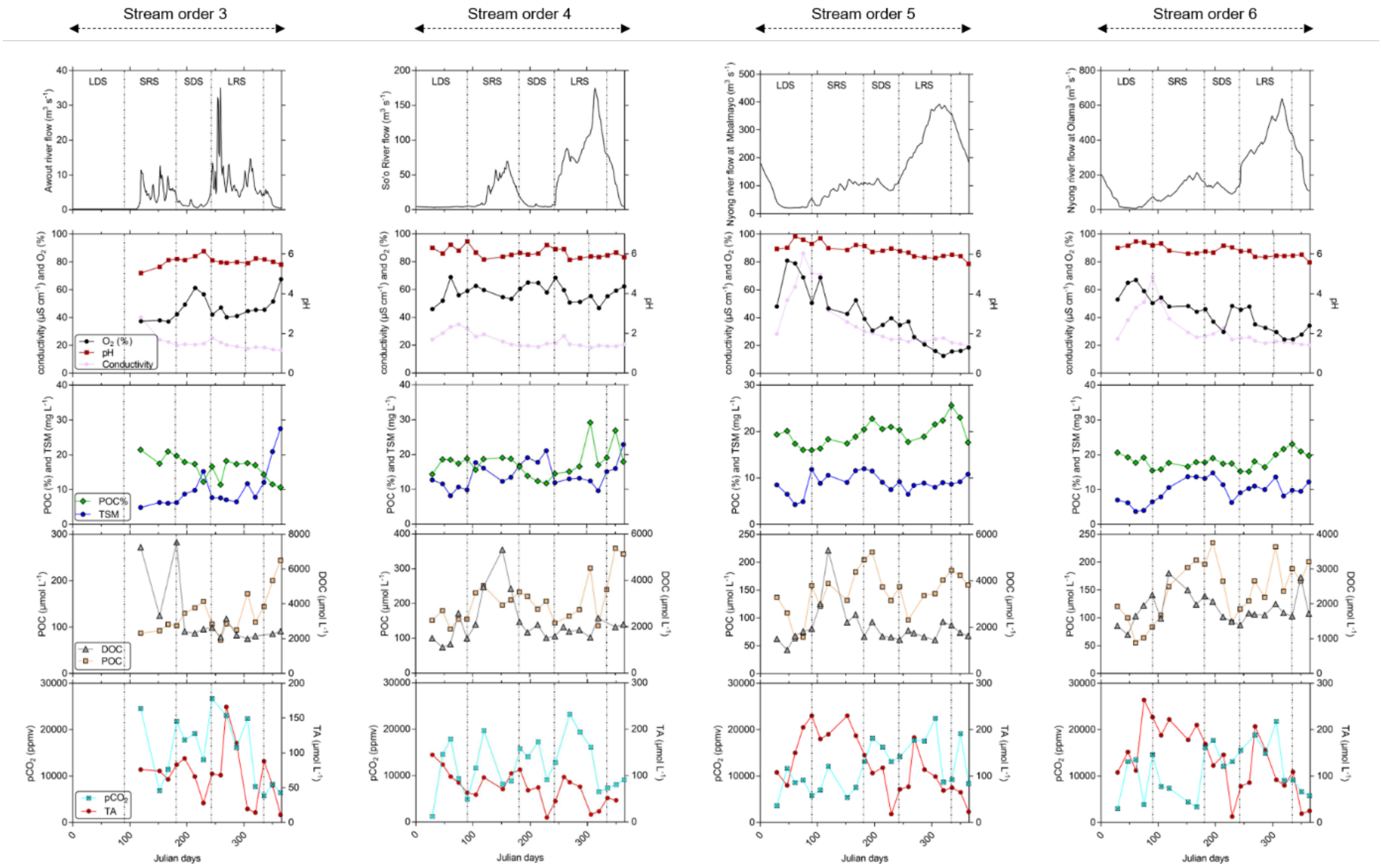


Figure 3: temporal variations of river discharge and carbon parameters in surface waters of the Nyong watershed

END OF THE GENERAL RESPONSE:

Reviewer (R#2) comments and author responses to manuscript bg-2021-69. Reviewer comments are given in normal style and with author responses in blue italic.

Comment: This manuscript by Moustapha et al. present a substantial collection of physicochemical and carbon data across stream orders in the Nyong basin in Cameroon to partition fluxes and attempt to close the C budget in this basin. The contribution of C flux data from tropical streams and rivers, groundwater, and from Africa is exciting to see, though the manuscript has several points that need attention before publication.

Answer: We thank the reviewer#1 for her/his overall positive evaluation of our manuscript.

Comment: There are general editing issues (typos, missing words) that will help focus the paper and a general polishing of the writing will help. In the results and discussion, words like 'obviously' and 'probably' should be removed following interpretation of the results the statistics.

Answer: We agree with the referee#1, none of the authors are native English speakers and, therefore, some sentences can be poorly written. In the revised version of our manuscript we will make and extra effort to carefully check English language, and if it is not enough we will go through English Editing services.

Comment: I believe a hypothesis driven approach will help the authors examine their data at a finer temporal scale and focus the broad application of statistics at a finer level to account for more of the variability in the dataset

Answer: Referee is right about a hypothesis driven approach; therefore, the objectives now reads: ". The first objective is to estimate the carbon mass balance of a first order catchment, the Mengong watershed, a nested sub-basin of the Nyong watershed. The estimated C fluxes are lateral hydrological inputs from land (i.e., from non-flooded forest groundwater) and from wetlands (i.e., from wetland) to the stream, river heterotopic respiration and the C degassed and exported from the stream. To the best of our knowledge, our study is the first to estimate lateral hydrological export of C both from wetland and from well-drained terrestrial ecosystem (i.e., from non-flooded forest groundwater) in a tropical catchment. In lines with recent studies in tropical rivers (Abril et al., 2014; Borges et al., 2015; 2019), we expect that lateral inputs of C from the wetland to the river network are significant in comparison with C exported laterally from non-flooded forest groundwater in this first order stream. The second objective of this study is evaluating the changes in C concentration across groundwater to different stream order over the seasons in the waters of the Nyong basin Ultimately, the variations of the carbon concentrations in the Nyong basin throughout a water cycle will be compared with those *observed in the Mengong sub-basin in order to evaluate how the biogeochemical cycle of carbon and its resulting CO2 emissions to the atmosphere in a large tropical basin is affected by the connectivity with the wetland domain."*

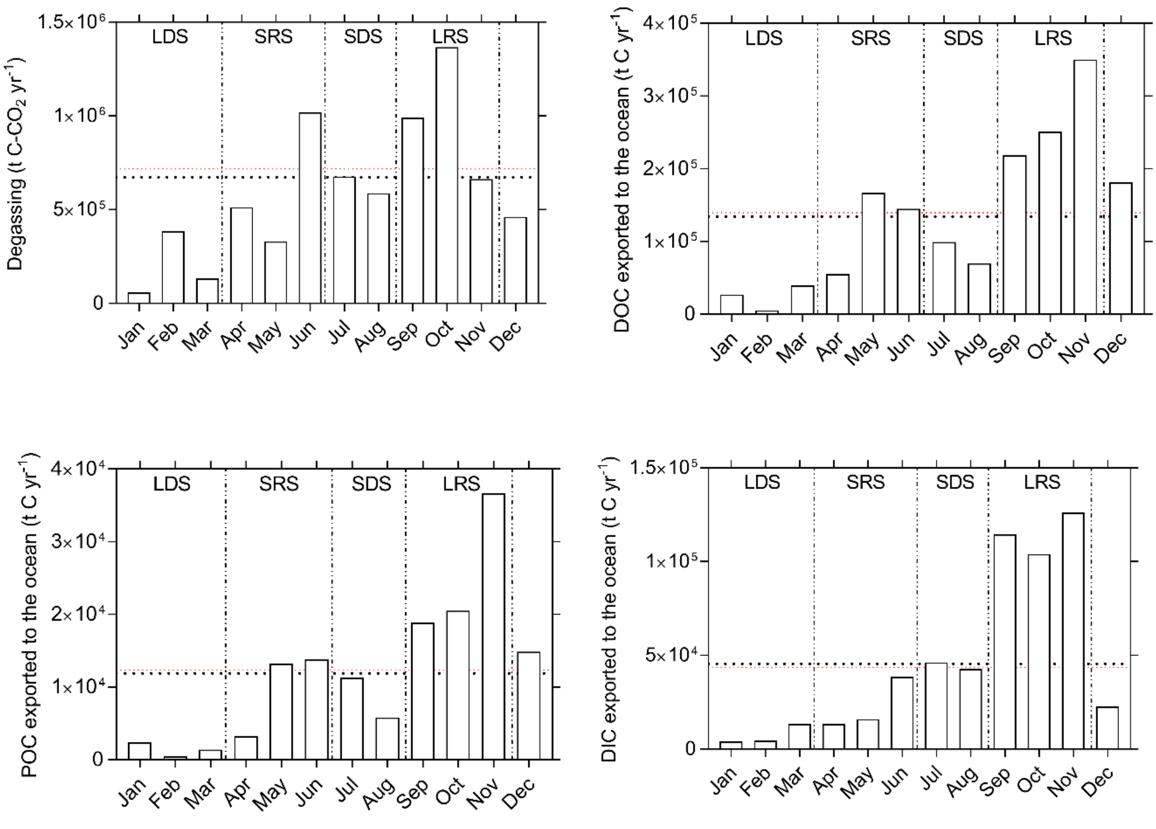
Comment: The data collection spans one year from 6 sites in the Nyong basin and attempts to separate inputs (terrestrial vs wetland groundwater) and exports (evasion and export). However, there should be greater focus towards a higher temporal resolution of the fortnightly measured variables and the hydrology. Separating the hydrograph and seasonality into 3 categorical sections is too coarse of an approach when a higher resolution is capable and likely overstates the continuous nature of seasonality. Further to this point, I don't recall much discussion of 2016 compared to 'the average' year. Particularly for evasion, more data spanning hydrologic variability is needed from across the globe and is in the dataset for the manuscript, but not presented

Answer: The reviewer#2 raised some very constructive and important points regarding the relationships between river flow and carbon parameters that indeed needed clarifications and further data exploration. Due to the strong hydrological temporality in tropical watersheds we acknowledge that the fact that we binned discharge into three periods was too coarse to establish relationships. Please see the general response, for the description of the hydrological functioning of the Mengong and the description of the hydrological and carbon parameters in the groundwater and surface waters

To explore further the point raised by the referee#1 and 2 we estimated in each stream order, carbon degassing from monthly concentrations of CO_2, rivers width and velocity and gas transfer velocity. We found that carbon degassing estimated from monthly concentration was 21.6±13.1 t C/km2/yr whereas carbon degassing estimated from annual averages of CO2, rivers width and velocity and gas transfer velocity, was 25.8±10.2 t C-CO2/km2/yr. Therefore, there is a little overestimation when we estimate carbon degassing from annual averages, but the two estimates are not significantly different. This difference might be due to the combination of monthly fluxes together with the monthly water surface variations which cannot be adequately account for with annual means of both parameters. This will be discussed in the revised manuscript.

We also estimated export of C to the ocean at the most downstream station from monthly concentration or annual averages. For DOC we found 4.8±3.6 (monthly) vs 5.0±0.4 (annual average). For POC we found 0.4±0.4 (monthly) vs 0.4±0.4 (annual average). For DIC, 1.6±1.5 (monthly) vs 1.8±0.4 (annual average) t C-CO2/km2/yr. Therefore, both estimations were very consistent.

In the revised manuscript, we will put the following figure that shows monthly fluxes of C export to the ocean and C degassing. The horizontal dashed lines represent the annual flux from monthly estimates (in red) and from yearly averages (in black)



To sum up, for the riverine C budget in the Mengong catchment we will keep estimations from yearly averages since our hydrological model does not allow a better temporal resolution. However, for fluxes at the entire Nyong watershed we will show both annual and monthly calculations and we will discuss the comparison. In addition, we will add some of the points raised by the referee#1 in the M&M section to inform the reader why we chose to rely on annual averages for the Mengong catchment.

Comment: The evaluation of C inputs and exclusion of respiration needs further discussion. The methods to measure pelagic respiration are stated, presented, and discussed, but not included into the budget. I fully agree that including this small amount of CO2 from instream processes is minimal compared to groundwater and wetland contributions but excluding it does not make sense to me. I see two options, though there may be others: 1) include the in-stream component respiration into the larger budget and empirically show this flux is much smaller the other input fluxes or 2) remove the respiration component entirely and refer to these data in supplementary material or as unpublished data that are not on the same order of magnitude as the other fluxes.

Answer: Actually, river respiration is based on organic carbon originating from the land or wetlands. Therefore, as we measured/estimated the flux of organic carbon entering the river network from land and wetlands, if we accounted for river heterotrophy in the total C budget, the organic carbon respired in the river would be counted twice (one time when it is exported from land or wetland to the surface network and another time when it is respired in the river).

However, in the revised manuscript, we will establish our carbon mass balance at the scale of a first order catchment and we will separate DOC and DIC budgets, as shown in the general response. Therefore, respiration is now included in the DOC budget as a loss term and included in the DIC budget as an input term.

Comment: The chamber method used leads me to think option 2. While the dark chamber or respiration chamber method is fine for large rivers and lakes (e.g. Borges et al. 2019), this approach focusing solely on pelagic processes in low order streams and rivers are not sufficient and understate the influence of the benthos in the transition from benthic to pelagic processes that occur in mid-order rivers (Reisinger et al. 2021). The authors acknowledge some of the issues with respiration in the discussion section, but they fail to include the data even though it is available

Answer: Yes, we agree with the referee and that is why we have chosen to add the mean benthic respiration occurring in tropical waters in our respiration estimates, as mentioned in the manuscript.

Comment: There are broad issues with units throughout the paper, and I recognize conversion between the units varies between scientific communities or journals. Presenting concentrations and fluxes as both moles and grams is a little confusing and the units need specification of what is being presented (mmol CO2-C or mmol CO2). Basin scale fluxes are presented as both Gg and tons of C. I would stick to the metric unit (Gg) or convert to Pg, which are used in other C flux studies and the readership for this paper will be more familiar with. The presentation of units between mol and g is something I deal with in my own work, so I empathize with the authors.

Answer: In the previous version of our manuscript, we relied on mole for fluxes related to the water surface area and on grams for fluxes related to the catchment surface area. However, it is true that it is confusing and therefore in the revised manuscript all fluxes will be show in t C/yr

Comment: There is a structural issue regarding the statistics that I think can be resolved with presenting hypotheses. At the end of the introduction, only one hypothesis is stated and is unclear to what extent this is revisited later. While this paper is a C budget and perhaps not best suited to hypotheses, I suggest adding several hypotheses to guide the presentation of the data and focus the statistical approach. There are interesting questions about temporal and spatial hydrologic variability, stream order position, rainfall, etc. that can be used to ask questions and lead to testable hypotheses within the dataset. These hypotheses can help clear up the statistical approach, which appears to have been a broad application of ANOVA to all the data (see specific comment below). I think a list of focused hypotheses will lead to a cleaner presentation of the statistics and results section of the paper, while also allowing the main question in the title of the paper to be answered explicitly.

Answer: The objective and assumptions now read: "The first objective is to estimate the carbon mass balance of a first order catchment, the Mengong watershed, a nested sub-basin of the Nyong watershed. The estimated C fluxes are lateral hydrological inputs from land (i.e., from non-flooded forest groundwater) and from wetlands (i.e., from wetland) to the stream, river heterotopic respiration and the C degassed and exported from the stream. To the best of our knowledge, our study is the first to estimate lateral hydrological export of C both from wetland and from well-drained terrestrial ecosystem (i.e., from non-flooded forest groundwater) in a tropical catchment. In lines with recent studies in tropical rivers (Abril et al., 2014; Borges et al., 2015; 2019), we expect that lateral inputs of C from the wetland to the river network are significant in comparison with C exported laterally from non-flooded forest groundwater in this first order stream. The second objective of this study is evaluating the changes in C concentration across groundwater to different stream order over the seasons in the waters of the Nyong basin Ultimately, the variations of the carbon concentrations in the Nyong basin throughout a water cycle will be compared with those observed in the Mengong sub-basin in order to evaluate how the biogeochemical cycle of carbon and its resulting CO2 emissions to the atmosphere in a large tropical basin is affected by the connectivity with the wetland domain."

Comment: L30-31: what are the units for respiration here? As mmol C, mmol CO2-C, mmol O2? Be specific. Also, in L29 can the units here be in metric (e.g. Pg C)

Answer: It was mmol CO2-C.

Note that we will rewrite the Abstract after the in-depth revision of the manuscript, it will be based on the following text:

“Tropical rivers emit large amounts of carbon (C) to the atmosphere but African rivers in the tropics are understudied in comparison to south American and Asian rivers. In addition, it is now well recognized that two different sources are fueling tropical rivers with carbon, namely, the land (soil and non-flooded forest groundwater) and wetlands. However, the partitioning of these two carbon sources is poorly known, especially in African rivers. We test the hypothesis that temporal patterns of carbon concentrations in surface waters of the Nyong watershed (Cameroon, 27800 km²) are due to the connectivity with wetlands, therefore increasing carbon concentrations during wet periods when the hydrological connectivity between surface waters and wetlands is higher. In addition, based on hydrological and carbon data gathered in a first order catchment that drains a mature forest in the hillside and a wetland at the bottom of the catchment, we estimated the carbon supply by the land (i.e., non-flooded forest groundwater that drains the hillside) and by wetland in a first order catchment (0.6 km²). In 2016, we measured fortnightly at 6 locations, in non-flooded forest groundwater and in streams from order 1 to 6, total alkalinity, dissolved inorganic C (DIC) used together with pH to compute pCO2, dissolved and particulate organic C (DOC and POC) and total suspended matter and with occasional measurements of river respiration. In the first order stream, DOC, POC and DIC increased significantly at the beginning of the wet periods because the drainages of the wetland increased whereas the same parameters decreased during the dry periods when the wetland shrinks. In higher stream orders, the same increase in DOC, POC and DIC occurs during wet periods but with a slight delay in comparison to the first order stream. This lag time is due to the time the water needs to flow from upstream to downstream showing that wetland in low-order streams are significant sources of C for downstream. In the first order catchment, we showed that the hydrological export of C from non-flooded forest groundwater (6.9±3.4 t C yr^{-1}) and the wetland (3.8±1.5 t C yr^{-1}) represent 0.7% of the NPP (1 495 t C yr^{-1}) of the catchment. About 60% (6.3±1.8 t C yr^{-1}) of this carbon exported to the stream was quickly degassed in the vicinity of the water resurgences whereas the river respiration represents 6.5% (0.4±0.4 t C yr^{-1}) of the degassing. In terms of quantity, the non-flooded forest groundwater exports 1.8 times more carbon than the wetland, however, in terms of quantity weighed by the surface area drained by each system, the wetland (27.9±12.5 t C km^{-2} yr^{-1}) exports 2.5 times more carbon than the non-flooded forest groundwater (11.2±5.4 t C km^{-2} yr^{-1}). At the scale of the Nyong watershed, the terrestrial primary productivity (NPP) was 4.3 10^7 t C yr^{-1} while we estimated a degassing of 7.2 10^5 t C yr^{-1}, a river heterotrophy of 5.9 10^4 t C yr^{-1} and a total riverine export of 2.0 10^5 t C yr^{-1}. Therefore, C degassing plus C export represents 2% of the NPP whereas the river respiration represents about 8% of the C degassing. The study shows the importance of lateral inputs from wetlands that represents about 35% of the total C exported to first order streams and thus ignoring the river–wetland connectivity can lead to the misrepresentation of C dynamics in tropical watersheds.

Comment: L40: I think the word ‘evasion’ is missing before the Raymond 2013 citation.

Answer: Yes, thank you for careful reading. This part now reads: “Despite their small surface area worldwide, inland waters have a critical role in the global carbon (C) cycle because they receive large amounts of C from terrestrial ecosystems that subsequently are processed and transferred to the atmosphere and the ocean (Allen and Pavelsky, 2018Cole et al., 2007; Ludwig et al., 1996; Meybeck, 1982). Besides, terrestrial aquatic ecosystems are significant hotspots of C dioxide (CO2) evasion (e.g., Raymond et al., 2013) because inland waters are usually supersaturated in CO2 compared to the overlying atmosphere.”

Comment: L41: ‘compare’ change to ‘compared’

Answer: Corrected as suggested

Comment: L44: See Drake et al. 2018, Tank et al. 2018, or Gómez-Gener et al. 2021 for updated values of global CO2 emissions from inland waters.

Answer: The sentence now reads: “Global inland waters emit 2.1-3.9 Pg CO2 yr-1 to the atmosphere (Raymond et al., 2013, Drake et al., 2018) with a potential underestimation of 35% due to the fact that inland waters are most of the time sampled during daytime (Gomez-Gener et al., 2021).

Comment: L82: I appreciate this explicit designation of the fluxes measured in this study. However, in the abstract, estimates of heterotrophic respiration were mentioned, but not here even though this production of CO2 through in-stream metabolism can be a small but non-trivial source of CO2 (Rocher-Ros et al. 2019).

Answer: Yes, we agree. The objectives now read as follow and explicitly refers to respiration: “The first objective is to estimate the carbon mass balance of a first order catchment, the Mengong watershed, a nested sub-basin of the Nyong watershed. The estimated C fluxes are lateral hydrological inputs from land (i.e., from non-flooded forest groundwater) and from wetlands (i.e., from wetland) to the stream, river heterotopic respiration and the C degassed and exported from the stream. To the best of our knowledge, our study is the first to estimate lateral hydrological export of C both from wetland and from well-drained terrestrial ecosystem (i.e., from non-flooded forest groundwater) in a tropical catchment. In lines with recent studies in tropical rivers (Abril et al., 2014; Borges et al., 2015; 2019), we expect that lateral inputs of C from the wetland to the river network are significant in comparison with C exported laterally *from non-flooded forest groundwater in this first order stream. The second objective of this study is evaluating the changes in C concentration across groundwater to different stream order over the seasons in the waters of the Nyong basin Ultimately, the variations of the carbon concentrations in the Nyong basin throughout a water cycle will be compared with those observed in the Mengong sub-basin in order to evaluate how the biogeochemical cycle of carbon and its resulting CO2 emissions to the atmosphere in a large tropical basin is affected by the connectivity with the wetland domain."*

Comment: L83: Only one hypothesis?

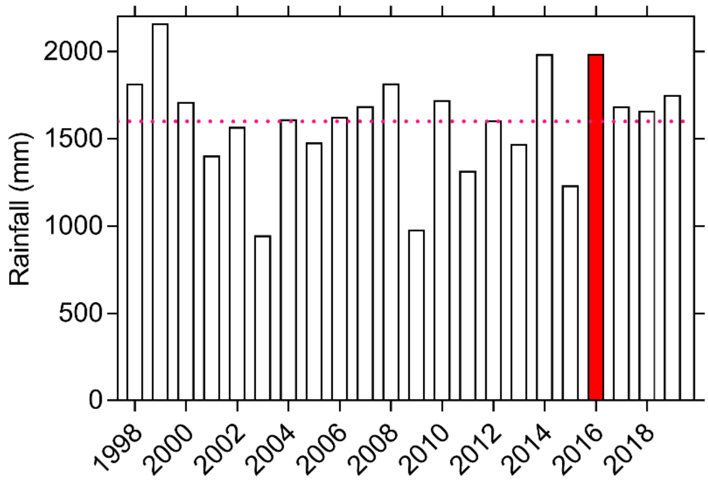
Answer: Yes, please see our response above

Comment: L99: Scientific names for these plants might be more useful to a broader audience

Answer: Yes, please see the general response

L102: Is the Mengong catchment within the Nyong (I see this is answered in L113)? Is the rainfall measured here characteristic of the wider basin? Help the reader by giving context to your study area

Answer: The Mengong catchment is an order-1 sub-catchment of the Nyong watershed, this will be clearly stated in the revised study site description. For the 1998-2019 period, the mean annual precipitation was 1600 ± 300 mm at the Mengong catchment (figure below that will be in supplementary in the revised manuscript). This is comparable to the mean annual precipitation (1600 ± 180 mm) reported by Suchel (1987) for the whole southern Cameroon plateau. Audry et al (2020) also showed that the spatial distribution of the rainfall in the Nyong River basin was remarkably homogeneous.



Comment: L106: I would re-cast ‘stream orders’; groundwater is not a stream order. Something like: ‘We sampled groundwater and surface waters, including streams across Strahler orders 1-6’ (if that is indeed the case).

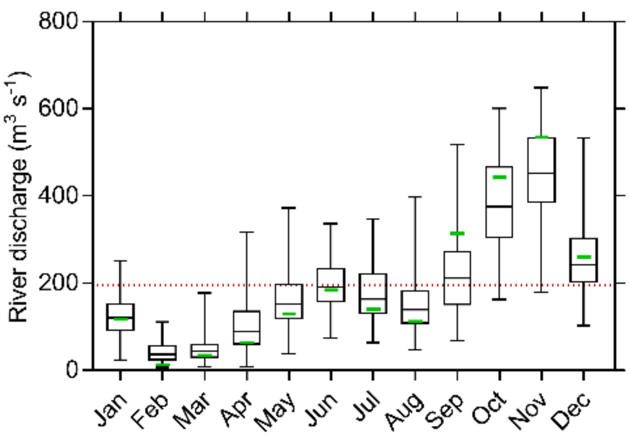
Answer: Yes, referee is right, thank you for notice. The text now reads: “We sampled non-flooded forest groundwater and surface waters, including streams across Strahler orders 1-6’; as suggested by the referee.

Comment: L107: ‘gauging gauges’. Change to ‘gauging stations’. The table has ‘stations’, I would follow that.

Answer: Thank you for careful reading. Corrected as suggested

Comment: L110: Is 200 m3/s the annual mean? What is the temporal variation, as you’ve indicated there is seasonality in flow? Also, typo ‘or’ is meant to be ‘of’. ‘Epxorted’ typo as well

Answer: We will put a new figure in the revised manuscript (in supplementary) showing historical mean and variability of monthly discharge for the Nyong River at Olama (Nyong outlet in this study) as follows:



The box plots represent the monthly discharge from 1998 to 2020, with minimum and maximum discharge for extreme box plots values, the green lines represent the average monthly discharge in 2016, and the red dashed line represents the yearly average discharge for the 1998 to 2020 period of 194.5 m3/s (very close to the yearly average discharge of 195 m3/s in 2016)

Comment: L113-126: This section should be shortened and edited

Answer: In the revised manuscript, we will deeply modify this section as following our general response.

Comment: L128: Personal preference for the Oxford comma

Answer: this will be modified

Comment: L163: I have to assume the cool box is also a dark box that prevents light. I'm not sure the pelagic approach to respiration is the most representative approach to study instream CO2 production especially in streams and small rivers, as much of the biological activity is occurring in the benthos. You may be underestimating the in-stream contribution to CO2

Answer: Yes, referee is right, but as discussed in the general response and in the responses above in this document, river heterotrophic respiration is a minor component of the riverine C budget in the Nyong watershed. The goal of this paper is not to estimate accurately river heterotrophy, it is mentioned to have an idea of the magnitude of this flux. However, we will add a mean benthic respiration to the measured pelagic respiration in the revised manuscript.

Comment: L203: We are in Section 2.4, I think you mean Section 2.3

Answer: yes, thank you for careful reading.

Comment: L205: be specific with units: mmol CO_2-C or mmol CO_2? You then convert to Gg in the next sentence. Pick one of grams or mols and stick to it through the whole paper. Again, in L209, why convert into t C? Most C flux units are as Pg or Gg. Make it easy for your readers by not over-converting between units L238:

Answer: In the previous version of our manuscript, we relied on mole for fluxes related to water surface area and on grams for fluxes related to catchment surface area. However, that is confusing and therefore all fluxes will be show in t C/yr in the revised manuscript

Comment: What are the explicit units here (CO_2-C or CO_2)? L236: what are the units an-1? Is this an annual basis (i.e. year-1)? Be consistent. L247: Unit issues again

Answer: yes, it was a typo, units are always in CO_2-C

Comment: L264: 'a given parameter'- be more explicit. You have measured a tremendous number of parameters, as fluxes, concentrations, etc. How is the reader to know if you 1) ran a correlation for everything measured or 2) focused on specific fluxes? I think there is an opportunity to be specific here in the statistical approach that would be aided by defining hypotheses or explicit relationships in the introduction that are missing in the introduction. I appreciate that the C accounting is not as a hypothesis driven approach, but you are also examining seasonality, stream order, and Q-C plots that could benefit from generating testable hypotheses in the data.

Answer: We take this comment seriously in the revised version. Anyway, the manuscript will be deeply revised in terms of content and organization (See General answer and answers to other reviewers). All new statistics to decipher the impact of hydrology on carbon biogeochemistry will be done only on measured parameters in order not to add additional uncertainty if using calculated parameters like horizontal or vertical fluxes. See for instance table 1 in our response to your comment on L282.

Comment: L272: what are the O_2 units? Be specific and say percent saturation.

Answer: corrected as suggested

Comment: L280: ‘peaked significantly’; peaked suggests change over time, but this comparison is between sites. Re-cast as ‘DO was highest in the So’o’. The wording of the statistical inference in L281-2 needs cleaning up.

Answer: Corrected as suggested

Comment: L282: Here are the data to answer a hypothesis related to temporal variation of these variables

Answer: Referee is right. As examples, in addition to the temporal variations described in the general answer, we will add results of correlation tests between river discharge and carbon parameters in the supplementary; an example for the Nyong at the Olama station follows:

		discharge vs. TA	discharge vs. pCO_2	discharge vs. DOC	discharge vs. TSM	discharge vs. POC%	discharge vs. POC	discharge vs. O_2	discharge vs. temperature	discharge vs. pH	discharge vs. conductivity
R (spearman)		-0,275	0,238	0,287	0,543	0,204	0,605	-0,856	-0,693	-0,814	-0,704
P (one-tailed)		0,1078	0,1498	0,0973	0,0045	0,1814	0,0014	<0,0001	0,0002	<0,0001	0,0001
P value summary		ns	ns	ns	**	ns	**	****	***	****	***

Comment: L324: 16% seems higher than ‘fairly balanced’. In the results section, I would simply state the ‘difference was 16%’ rather than qualifying as ‘fairly balanced’, which is a judgement that merits discussion later in the paper.

Answer: We agree with the referee we will remove fairly balanced. Please see the explanation of the new carbon budget in the Mengong catchment in the general answer. Discussion will be included in the revised manuscript based on the concomitant temporal change in areal fluxes and surface area of the rivers in the watershed.

Comment: L341: ‘soil OM respiration’ reads as if the soil OM is doing the respiration. Re-cast as ‘respiration of soil OM in the unsaturated zone’

Answer: corrected as suggested

Comment: L343: ‘probably’- do the papers cited at the end of this sentence give any clarity or more definitive data to guide this statement?

Answer: The papers cited here discussed the different origins of CO2 in groundwater, pedological and geographical context of these study will be added in the revised version of the manuscript.

Comment: L352: '50 times higher'; be explicit, what is the concentration or ppmv?

Answer: On average throughout the year, groundwater pCO2 was ~50 times higher (78 800±40 110 ppmv) than the atmospheric value (400 ppmv) showing that non-flooded forest groundwater is a significant source of CO2 for the river network of the Nyong basin (Table 3).

Comment: L355-6: 'During base flow, precipitation was low…' I hope so! Switch the order of this statement 'Low rainfall resulted in lower flows than the other seasons…' or similar. Same language issues in L357.

Answer: Yes, thank you for careful reading. The revised manuscript will be modified according to our general answer. Therefore, we will not use the terms base, medium or high flows.

Comment: L443- 'invested'; not sure that is the word to use in this case

Answer: We meant invaded

Comment: L449: Based on your budget, but you acknowledge you didn't include respiration, which is a flux you measured but chose not to include! I agree that groundwater and wetlands are likely large contributors to stream C but you have the data to make the comparison to in-stream processes. You make this comparison in L454, but I don't see why not include in the budget, even it its less than the error of the other input fluxes

Answer: Referee is right. Please see our general answer where we present the revised budget accounting for respiration.

Comment: L453: typo 'trough'; delete everything after 'atmosphere'

Answer: corrected as suggested

Comment: L 474: there is no discussion of the 16% difference mentioned in the results, that seems important to bring up again

Answer: In our revised riverine budget at the Mengong catchment scale (see the general answer), we still found an imbalance of 17% between C inputs and outputs. Note, however, that considering the temporal variations (standard deviation), C inputs and outputs fluxes are not statistically different. However, we will discuss this difference in the revised manuscript (overestimation of the inputs like heterotrophic respiration or underestimation of the outputs *like CO2 outgassing and the concomitant temporal change in areal fluxes and surface area of the rivers in the watershed).*

Comment: Table 1- how representative are each of these streams of the broader orders the represent across the basin? 'Averaged annual' change to 'Mean annual…' and use yr-1 in the units. Can you provide a brief overview of the gauging stations as a footnote or in a supplementary file?

Answer: It is a very tough question to know how representative are each of these streams of the broader orders they represent across the basin. Most of the streams in this catchment are not accessible (no road) and were never studied. However, according to several studies, the sampling sites chosen for the M-tropics project are considered to be representative of the Nyong basin (e.g., Boeglin et al., 2002; Nkoundou 2008, Viers et al., 2000).

Please see the general answer for the description of the Mengong catchment, and a brief overview of the other gauging stations follows:

(1) The Awout River flows for about 30 km in a marshy riverbed.

(2) The So'o River is located at an altitude of 634 m in the So'o basin. The latter is the southern forest extension of the large Nyong basin. The So'o river is the main tributary on the left bank of the Nyong River.

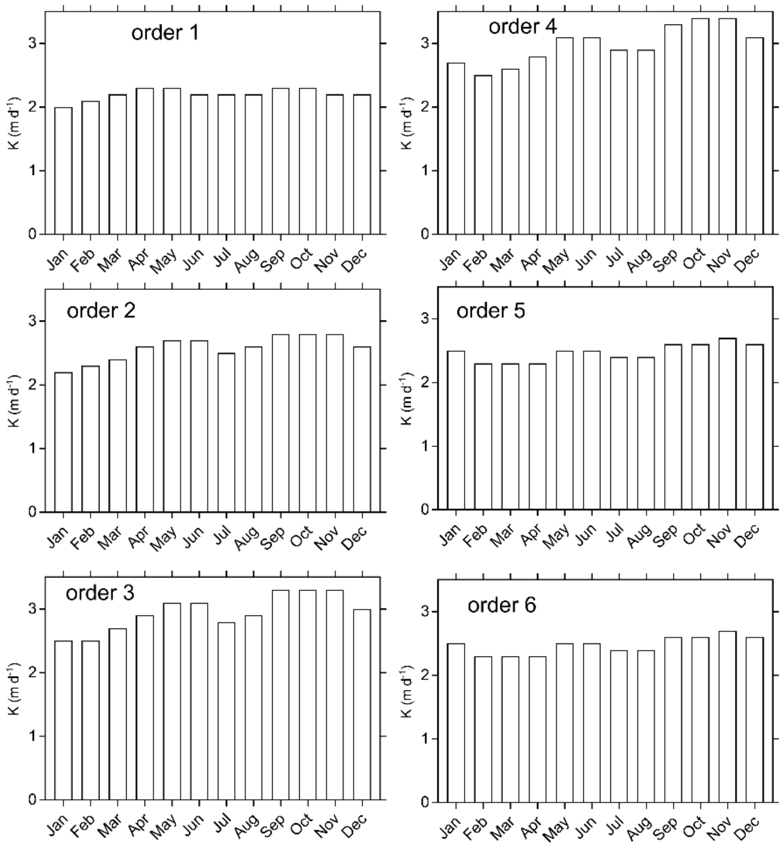
(3) Mbalmayo sampling station represents the upstream course of the Nyong basin before the confluence with the So'o. The upstream Nyong flows slowly on a very gentle slope, which induces riparian wetlands (Olivry, 1986). Photo showing the Nyong River at Mbalmayo (From Audry et al., 2020)

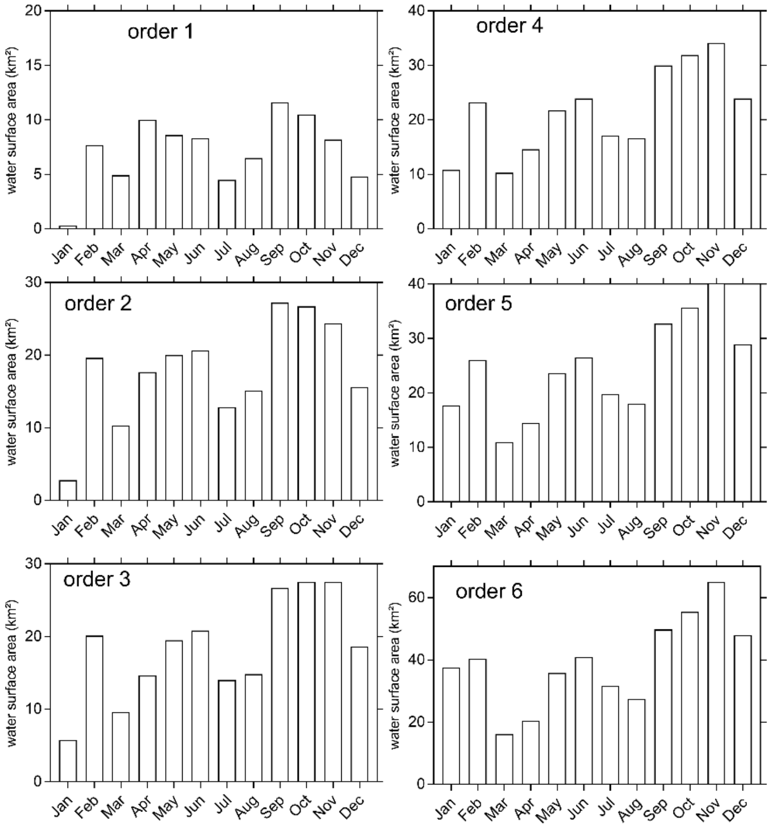
(4) Olama station represents the outlet of the upstream Nyong basin after the confluence with the So'o River, 30 km downstream from Mbalmayo station. The relief remains low here with an average slope of 0.15 ‰ but with the absence of riparian wetlands (Olivry, 1986).

Comment: Table 4- Is the first column the different stream orders? Why was respiration only measured in 2 sites, the text says in all sites? The units in the table are an issue: umol, mmol, and Gg. The gas exchange rates seem low; was there any attempt to evaluate change in k600 over time and changes due to changes in discharge?

Answer: The first column in Table 4 represents stream orders. The respiration was measured only occasionally at two sites and this was not mention clearly enough in the text. The gas exchange rates are low (even though it is in the range estimated by Borges et al., 2015 in African streams, which was 2.7±2.4 m/d) because the river slopes are very low, the Nyong watershed is indeed located in the southern Cameroon plateau that exhibited very gentle slopes.

As also suggested by the referee 1, in the revised manuscript we estimate carbon degassing at the watershed scale from monthly variations of river discharges, water surface area, and gas exchange rates. Please see the detailed response above in this document. Figures showing monthly variations of gas exchange rates and water surface area follows:





Comment: Figure 2- are 'Days' day of the year? Day since start of the project? Days in the water year? Please change to a date to help your readers. Also, why not show the data from all the streams with a gauging station?

Answer: It is Julian days for the year 2016, starting on Jan, 1st. Each sampled stream is also a gauging station (as mentioned in the manuscript). In addition, the figure 2 shows hydrological data of all gauging stations (and thus of all sampled streams).

Comment: Figure 3- If Tukey's post-hoc test compared the seasons, why not use the groups from that test above or below each boxplot to designate the significant groupings? The horizontal bars and asterisks are distracting. The axis text and titles could be bigger. Also, is this figure and Table 2 showing the same information? I think the figure is more valuable than the table. Figure 4, 5- same comment about Tukey letter groupings as Fig 3

Answer: These figures will be removed from the revised manuscript as explained in the general comments, we will not binned river discharge into three periods only because it was too coarse to establish relationships and to well describe the variations of carbon concentrations with discharge.