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High organic carbon burial but high potential for methane ebullition in the sediments of an Amazonian reservoir

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Abstract. Reservoir sediments sequester significant amounts of organic carbon (OC), but at the same time, high amounts of methane (CH_4) can be produced during degradation of sediment OC. Hydropower is expanding in the Amazon basin, but the potential effects of river damming on the biogeochemistry of the Amazon river system can at present not be gauged due to a lack of studies. Here we present results from the first investigation of OC burial and CH_4 concentrations in the sediments of an Amazonian reservoir. We performed sub-bottom profiling, sediment coring and sediment pore water analysis in the Curuá-Una reservoir (Amazon, Brazil) during rising and falling water periods. A mean sediment accumulation rate of 0.6 cm yr^{-1} and a mean OC burial rate of 91 g C m^{-2} yr^{-1} were found, which is the highest OC burial rate on record for low-latitude reservoirs, probably resulting from high OC deposition onto the sediment compensating for high OC mineralization at 28-30°C water temperature. Elevated OC burial was found near the dam, and close to major river inflow areas. C:N ratios between 10.3 and 17 (mean ± SD: 12.9 ± 2.1) indicate that both land-derived and aquatic OC accumulate in CUN sediments. About 29% of the sediment pore water samples had dissolved CH_4 close to saturation concentration, a higher share than other hydroelectric reservoirs, indicating a high potential for CH_4 ebullition, particularly in river inflow areas.

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Introduction

Although freshwater ecosystems represent a small fraction of the global area (~4% of terrestrial area) (Downing et al., 2012; Verpoorter et al., 2014), they play an important role in the global carbon cycle, emitting and burying carbon during transport from land to the oceans (Cole et al., 2007; Tranvik et al., 2009). Many studies have been conducted on inland water carbon emissions, while the organic carbon (OC) burial in inland water sediments is comparatively understudied (Raymond et al., 2013; Mendonça et al., 2017). Since a part of the buried OC may offset a share of greenhouse gas emission, it is essential to include OC burial in estimations the carbon balance of inland water ecosystems (Kortelainen et al., 2013; Mendonça et al., 2017).

The OC burial rate varies both in space and time due to many factors, such as land cover, hydrological conditions, OC and nutrient input and climate change (Radbourne et al., 2017). Several studies have shown that reservoirs bury more OC per unit area than lakes, rivers and oceans (Mulholland and Elwood, 1982; Mendonça et al., 2017), which may be attributed to the high sedimentation rate caused by the extensive sediment trapping when water flow is dammed (Vörösmarty et al., 2003). Considering the importance of reservoirs as a carbon sink (~40% of total inland water OC burial; Mendonça et al., 2017) and the increasing number of hydroelectric dams (Zarfl et al., 2015), the limited number of studies on OC burial in reservoirs severely hampers the understanding of this important component in the carbon balance of the continents (Mendonça et al., 2017). In particular, large regions of the Earth are at present completely unsampled concerning inland water carbon burial.

To the best of our knowledge, OC burial has so far not been studied in an Amazonian reservoir. However, temperature and runoff were identified as important drivers of OC burial in

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lakes and reservoirs (Mendonça et al., 2017), and OC burial in Amazonian floodplain lakes was reported to be much higher than in other lakes (Sanders et al., 2017). These observations suggest that reservoirs in the Amazon area may bury OC at a comparatively high rate. Moreover, many new hydropower dams are planned in the Amazon due to the high potential of the area for hydroelectricity (da Silva Soito and Freitas, 2011; Winemiller et al., 2016). However, there is currently no data to gauge the potential effect of hydropower expansion in the Amazon on carbon burial.

On the other hand, it has been shown that reservoirs can be strong sources of methane (CH_4) to the atmosphere (Deemer et al., 2016). Several studies have shown a positive relationship between CH_4 production and temperature in freshwater ecosystems (Marotta et al., 2014; Wik et al., 2014; Yvon-Durocher et al., 2014; DelSontro et al., 2016; Aben et al., 2017), and also organic matter supply to sediment is an important regulator CH_4 production and emission (Sobek et al., 2012; Grasset et al., 2018). Thus, tropical reservoirs, especially those situated in highly productive humid tropical biomes such as the Amazon, may produce more CH_4 than temperate ones due to higher annual temperatures and availability of organic matter in their sediments (Barros et al., 2011; Mendonça et al., 2012; Fearnside and Pueyo, 2012; Almeida et al., 2013), even if highly-emitting reservoirs can also be situated in temperate regions (Deemer et al., 2016). However, most of the CH_4 is emitted from reservoirs via ebullition (i.e., gas bubbles), which is very difficult to measure due to its strong variability in space and time (McGinnis et al., 2006; Deemer et al., 2016). Measurements of dissolved CH_4 concentration in sediment pore water may, therefore, help to identify if ebullition is likely to occur (CH_4 concentrations close to the sediment saturation), and thus to judge if the sediments act mainly as carbon sinks, or also CH_4 sources.

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Since both OC burial and CH_4 production take place in sediments, and since both OC burial and CH_4 emission may potentially be high in reservoirs in the Amazon area, we conducted a study on the sediments of an Amazonian reservoir during hydrologically different seasons, to present the first whole-reservoir OC burial estimate, and the first mapping of concentrations of CH_4 in sediment pore water.

Material and methods

Study area

Curuá-Una is an Amazonian reservoir (CUN; 2°50′ S 54°18′ W) located in the Pará state (North of Brazil), created in 1977, and used mainly to produce energy. The mean water depth of CUN is 6 m (Fearnside, 2005;Paranaíba et al., 2018) and it has a maximum flooded area of 72 km^2 (Fearnside, 2005). The main tributary is the Curuá-Una River, contributing with most of its water discharge (57.4%), but rivers Moju (11.7%), Mojuí (4.4%), Poraquê (3.2%) and other small ones (2.9%) are also important (Fearnside, 2005). The catchments of the largest tributaries, entering from the south, consist mainly of tropical rainforest, while the northwestern tributaries also contain a fraction (up to 41%) of managed land.

The reservoir is characterized by a high amount of flooded dead trees (covering 90% of the total reservoir area), which may be expected to decrease water flow and promote sedimentation. According to a previous study (Paranaíba et al., 2018), CUN is oligotrophic (total nitrogen: 0.7 mg L^{-1}; total phosphorus: 0.02 mg L^{-1}), the surface water is warm (30.1 ± 1.4 °C), slightly acidic (pH of 6.1 ± 0.7), with low conductivity (16 ± 11 µS cm^{-1}) and moderately oxygenated (6.7 ± 1.9 mg L^{-1}). Measurements with a multiparameter sonde (YSI 6600 V2) along 36 depth profiles distributed across the reservoir at two hydrologically different sampling

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occasions showed that the relatively shallow water column (mean depth: 6 m) is generally well-mixed in CUN, with 5.1 ± 1.2 mg L^{-1} of dissolved oxygen and 28.3 ± 2.1 ºC in the bottom (data not shown).

Sampling

We carried out two samplings in the CUN reservoir. In February 2016, during the rising water period (**Fig. S1**), we used an Innomar SES-2000 parametric sub-bottom profiler operating at 100 kHz (primary frequency) and 15 kHz (secondary frequency) to determine the bathymetry and sediment thickness (similar to Mendonça et al. 2014). Sediment thickness was difficult to observe, though, presumably because of the widespread presence of gas bubbles in the sediment which reflect the sound waves very efficiently, preventing them from reaching the sub-bottom layer. Therefore, OC burial rates were determined from sediment cores only. In September 2017, during the falling water period (**Fig. S1**), additional sediment cores were then taken to cover the reservoir as much as possible.

We took a total of 114 sediment cores during the two sampling occasions, spatially distributed along the reservoir to estimate OC burial rates (**Fig. 1**). Cores were retrieved using a gravity corer equipped with a hammer device (UWITEC, Mondsee, Austria) to sample the entire sediment layer, including the pre-flooding material. The transition between pre-flooded material and post-flooding sediment was visually identified (**Fig. S2**) and the thickness of the post-flooding sediment was noted. All cores were used to estimate sediment thickness. Nineteen sediment cores spread out over the reservoir were sliced in 2 cm thick slices and dried at 40 ºC for further laboratory analysis. The samples were weighed before and after the drying process and the results are, then, expressed in dry weight.

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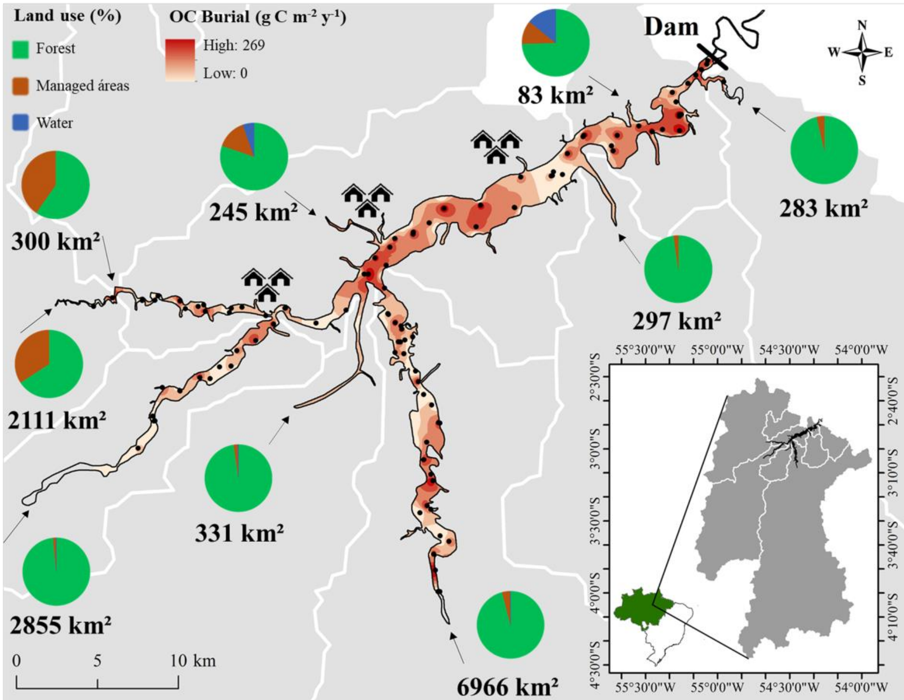

Figure 1. Organic Carbon Burial rate (OC burial; g C m^{-2} yr^{-1}) and land cover of Curuá-Una reservoir. The circles show the land cover of each sub-catchment. The numbers near the circles show the area in km² for each sub-catchment. The black dots represent the sediment sampling sites to estimate SAR and OC burial rates. The arrows represent the main rivers inflow. The houses represent settlements at the reservoir. The bottom-right map shows the location of the reservoir in Brazil (the green area is the Brazilian Amazon region) and the total extension of each sub-catchment.

In both sampling campaigns, cores were taken for the analysis of pore water CH_4 concentration profiles (n = 16 in February 2016 and n = 9 in September 2017). Of the nine cores taken in September 2017, eight were situated at sites previously sampled in February 2016, to compare the CH_4 concentrations between sampling occasions. It is difficult to sample the exactly same location at different periods due to the water level changes, GPS error and navigation. Thus, the repeated samplings at these eight sites were approximately within < 100 m distance.

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Air pressure and temperature were measured with a portable anemometer (Skymaster SpeedTech SM-28, accuracy: 3%), water depth was measured with a depth gauge (Hondex PS-7), and sediment temperature with a thermometer (Incoterm), which was inserted into the sediment right after core retrieval.

Carbon and nitrogen analysis

OC and total nitrogen (TN) concentrations were determined in the 19 cores, which were distributed across the reservoir area. In each of these cores, the first and second layer (0 to 4 cm deep), the last sediment layer above the pre-flooding soil surface, and about one sample every 8 cm in between were analyzed. Before measurement, dried sediment was ground in a Planetary Ball Mill (Retsch PM 100) equipped with stainless steel cup and balls. Sediment was packed in pressed tin capsules and analyzed with a Costech 4010 elemental analyzer. The presence of carbonates was checked in the samples via adding drops of acid, and no evidence of solid carbonates was found. Linear interpolation was used to derive OC and TN concentrations of layers that were not measured. The molar C:N ratio in the surface layers was then calculated.

CH_4 concentration in pore water

The CH_4 concentration in pore water was measured (according to Sobek et al., 2012 and Mendonça et al., 2016) to determine if CH_4 is close to saturation concentration and, thus, prone to form gas bubbles. The top 20 cm (February 2016) or 40 cm (September 2017) of the sediment cores were sampled every 2 cm. Deeper sediment was sampled every 4 cm until the bottom or pre-flooding material. Using a core liner with side ports, 2 ml of sediment were collected using a syringe with a cut-off tip, added to a glass vial with 5 ml of distilled water, and closed with a 10 mm thick butyl rubber stopper. The glass vials were then shaken for one minute and the gas

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extracted by a 10 ml syringe with a needle. The CH_4 concentration in pore water was measured by an Ultraportable Greenhouse Gas Analyzer (UGGA, Los Gatos Research) with a custom-made sample injection port, and the peaks were integrated using an R script (RStudio Version 1.1.383). The saturation concentration of CH_4 in the sediments was calculated based on the air pressure, water depth, sediment temperature, and sample depth within the sediment core. Then, the percentage of samples close to saturation concentration was estimated, assuming that a CH_4 concentration >80% of saturation concentration is indicative of a sediment layer prone to contain a gas bubble; this assumption mirrors the potential loss of gas from the sediment during coring and sampling.

Data analysis

OC mass (g C) in each sediment slice was calculated as OC content (g C g^{-1}) multiplied by dry sediment mass (g). Total OC mass (g C) in the cores was the sum of OC mass in all post-flooding sediment samples. Then, OC burial rates (g C m^{-2} yr^{-1}) for each site were calculated using the total OC mass (g C), core surface area (2.8×10^{-3} m^2) and the reservoir age (considering the years of sampling and the reservoir creation). The average sediment accumulation rate (SAR; cm yr^{-1}) was obtained by the ratio of post-flooding sediment thickness and the reservoir age. SAR was positively correlated to OC burial rate in the sites (see Results; $y = 159.03x - 4.4212$; $R^2 = 0.87$; **Fig. S3**), and used to estimate the OC burial rate (g C m^{-2} yr^{-1}) from SAR for the coring sites where OC content was not analyzed. The resulting OC burial rate was used to extrapolate the total amount of OC buried per year considering the entire flooded area (72 km^2) and the age of the reservoir (40 years).

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Spatial analyses were performed in ArcGIS 10.3.1 (ESRI). We used the Inverse Distance Weighted algorithm (IDW, cell size of approximately 22 m x 22 m) to interpolate the coring site values and produce spatially resolved maps of SAR, OC burial rate, pore water CH_4 saturation, and C:N ratio for the whole reservoir.

Land cover data was derived from maps of 1 km resolution (Global Land Cover Project, GLC2000), made available by the European Commission's science and knowledge service, including 23 land cover classes. The classes found in the CUN watershed were then grouped in three main classes: (1) forest (tree cover, natural vegetation, shrub, and herbaceous cover); (2) managed areas (cultivated and managed areas, cropland and bare areas); (3) and water bodies. The extent of CUN watershed and sub-basins were identified using the WWF HydroBASINS tool (HydroSHEDS, 2019).

Results and discussion

Overview

The highest SAR and OC burial rates were observed near the dam, at the confluence of the largest inflowing rivers, and in the inflow area of the main tributary (Curuá-Una river; **Fig. 1**). An average C:N ratio of 12.9 ± 2.1 (mean ± SD) was found in CUN, with high values near the dam area and at the river inflows (**Fig. 2**). 29% of the pore water CH_4 concentration samples were >80% of saturation concentration, most of them located at the river inflows and in Curuá-Una river (**Fig. 3** and **4**).

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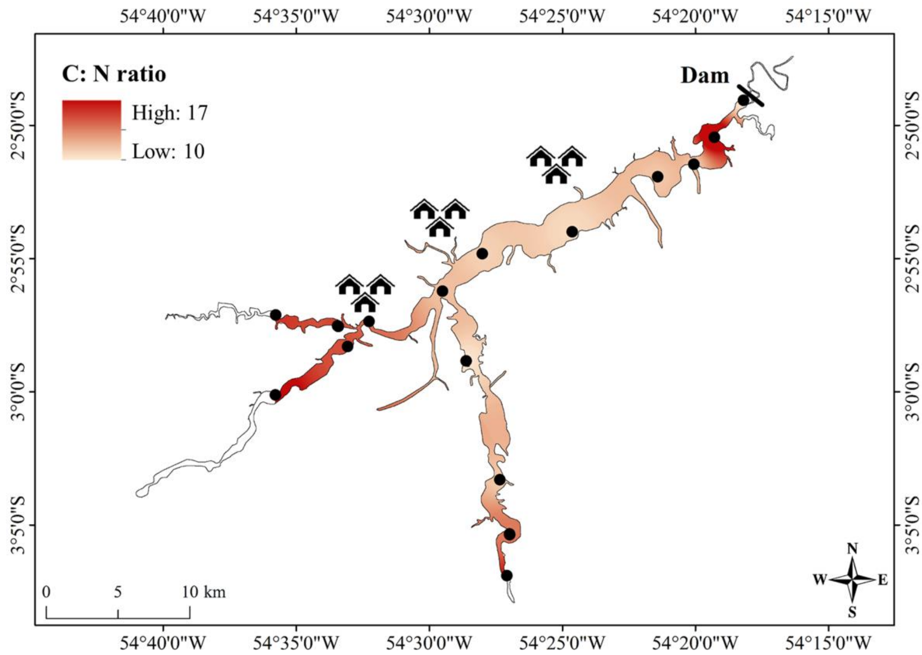

Figure 2. C:N ratio of surface sediment in Curuá-Una reservoir. The black dots represent the sampling sites. The houses represent the settlements at the reservoir.

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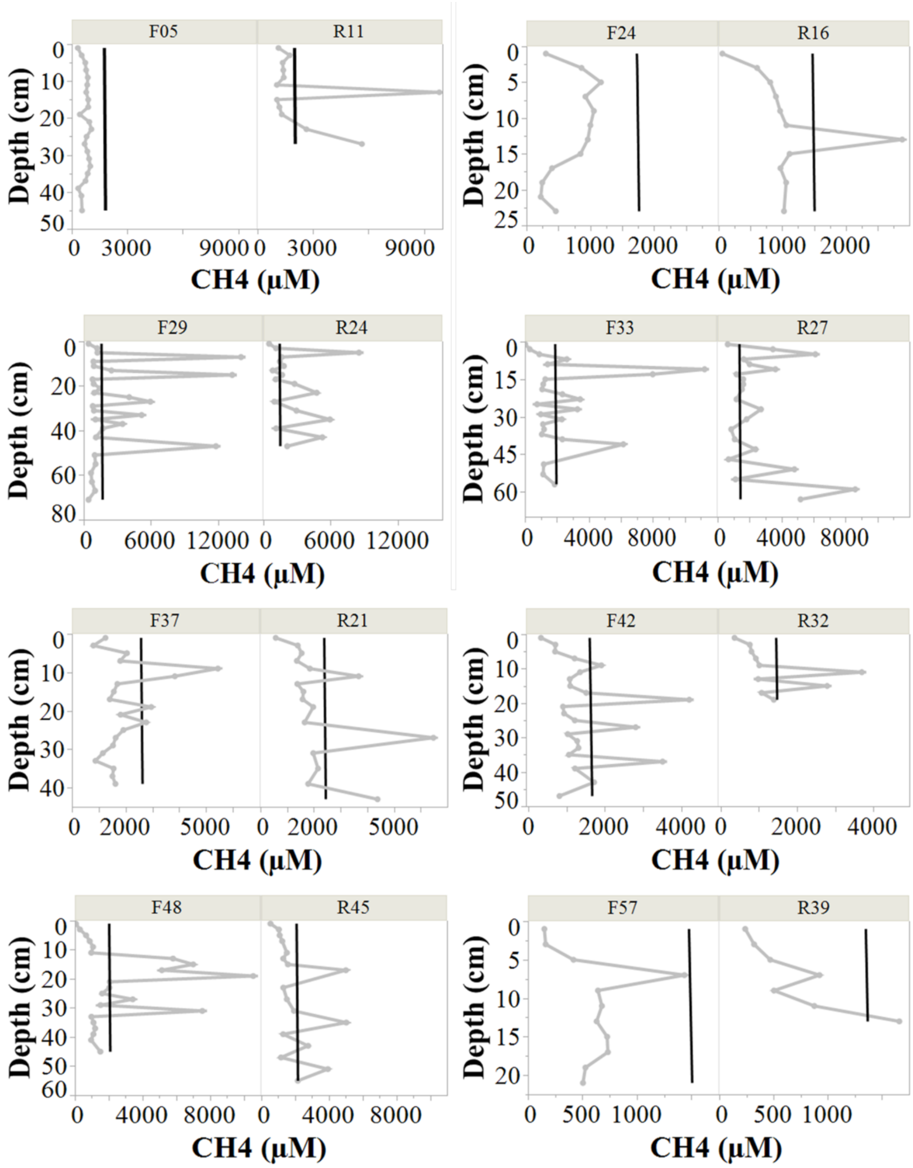

Figure 3. Pore water CH_4 profiles during rising (R) and falling (F) water periods at eight different sampling sites across the reservoir. Black lines represent the CH_4 saturation line (µM) and grey lines represent the measured CH_4 concentration (µM) over sediment depth.

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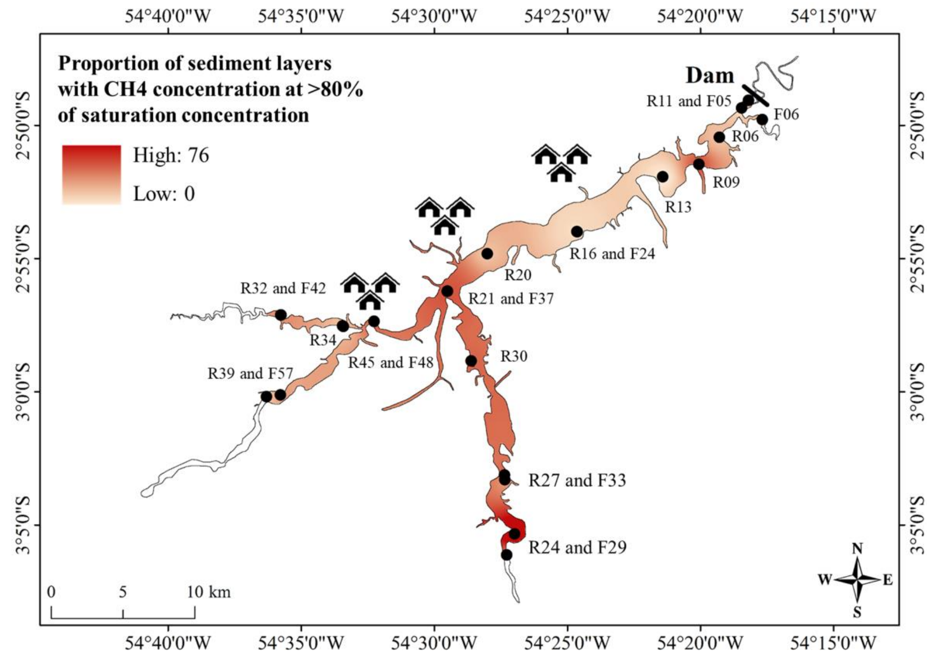

Figure 4. Percentage of sediment layers with CH_4 concentration >80% saturation. The black dots represent the sampling sites to produce the interpolation. The houses represent the settlements at the reservoir.

Sediment accumulation and organic carbon burial rates

SAR in the coring sites (n = 114) varied from 0 to 1.7 cm yr^{-1} (mean ± SD of 0.6 ± 0.4 cm yr^{-1}, **Table S1**, **S2**, **S3**). In some areas of rocky or sandy bottom, especially near river inflows and along the main river bed, sediment could not be retrieved with our corer and SAR was considered as zero (total of 10 sites). A previous study in an Amazonian floodplain lake (Lago Grande de Curuai) showed a similar SAR ranging from 0.4 to 1.3 cm yr^{-1} (1 ± 0.4 cm yr^{-1}, Moreira-Turcq et al., 2004). CUN showed an average SAR slightly higher than non-Amazonian reservoirs in Brazil (Mendonça et al., 2014: 0.5 cm yr^{-1}; Franklin et al., 2016: 0.4 cm yr^{-1}). Midwestern US reservoirs showed a large SAR range varying from 0.4 to 6.9 cm yr^{-1} (2.1 ± 1.7 cm yr^{-1}, Knoll et al., 2014). However, these reservoirs are smaller than CUN and presumably receive larger sediment inputs from erosion of agricultural land, both aspects contributing to higher SAR. We also note that

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comparisons of mean SAR between studies may be complicated by different sampling schemes – while in some studies sites along the margins with zero sedimentation were retrieved (e.g. Mendonça et al., 2014; our study), in other studies it was not (Moreira-Turcq et al., 2004; Knoll et al., 2014).

OC burial rate in the coring sites (n = 114) varied from 0 to 269 g C m^{-2} yr^{-1} (mean ± SD of 91 ± 61 g C m^{-1} yr^{-1}, **Table S1**, **S2**, **S3**). The highest values of OC burial were observed near the dam, in the meeting of inflowing rivers, and the inflow area of the main tributary, Curuá-Una River (**Fig. 1**). Typically, the sedimentation rate is higher in the inflow areas and lower near the shores (Morris and Fan, 1998; Sedláček et al., 2016). When the river enters the reservoir, the water flow tends to decrease, favoring the deposition of suspended particles (Fisher, 1983; Scully et al., 2003). CUN also showed high SAR in the inflow areas, but in contrast to other reservoirs (e.g. Mendonça et al., 2014), we did not observe any decrease in SAR towards the margins. Sediment accumulation across the entire reservoir area is favored by the shallow topography of the area, and by the presence of dead tree trunks, which reduce water flow and wave-driven resuspension, including in the margins. Accordingly, our data show that SAR was randomly distributed in relation to water column depth (**Fig. S4**). Some reservoirs show higher sedimentation rates near the dam (Morris and Fan, 1998; Sedláček et al., 2016), which is sometimes called 'muddy lake area', and happens in reservoirs where the fine sediment is transported all the way to the dam (Morris and Fan, 1998; Jenzer Althaus et al., 2009; Sedláček et al., 2016; Schleiss et al., 2016). CUN may be one of those cases (**Fig. 1**), possibly because water retention time is low in the main river channel which is narrow and well separated from the dead tree area, permitting sediment transportation until the deep dam area (**Fig. S5**), where sediments tend to accumulate (Lehman, 1975; Blais and Kalff, 1995). Similarly, the confluence

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of the major tributaries is rather deep and receives much of the terrestrial sediment load, which may explain elevated OC burial in the confluence area (**Fig. 1**).

Our sampling was representative of the whole system, from the margins, where there is a greater presence of dead tree trunks, to the river bed, where the sedimentation was smaller (**Fig. 1**). Therefore, we used the mean OC burial rate, derived from sediment coring at 114 sites, for extrapolation to the whole system. The burial rate for the entire CUN reservoir was 6.5 x 10^{10} g C yr^{-1}, corresponding to an accumulation of 0.3 Tg C in CUN sediments since its construction. Comparing with other hydroelectric reservoirs at low latitudes, OC burial in CUN was high. OC burial rate in sub-tropical Lake Kariba was four times lower (23 g C m^{-2} yr^{-1}, Zimbabwe, Kunz et al., 2011), and also the sub-tropical reservoir Mascarenhas de Morais (42.2 g C m^{-2} yr^{-1}, Brazil, Mendonça et al., 2014) and other sub-tropical reservoirs (40.40 ± 28.11 g C m^{-2} yr^{-1}, Brazil, Sikar et al., 2009) had only about half of the OC burial rate compared to CUN. Amazonian floodplain lakes showed higher OC burial rate than CUN (266 ± 57 g C m^{-2} yr^{-1}; Sanders et al., 2017). However, these Amazonian floodplain lakes are smaller than CUN, which may result in a higher SAR since there is little area for sediment deposition but high sediment load from the river during periods of high discharge.

Burial rates smaller than that of CUN were observed in in some reservoirs located in colder climate zones (boreal Eastmain reservoir: 32.9 g C m^{-2} yr^{-1}, Canada, Teodoru et al., 2012); temperate Xinanjiang reservoir: 43.4 g C m^{-2} yr^{-1}, China, (Wang et al., 2017); temperate Huairou water supply reservoir: 62.3 g C m^{-2} yr^{-1}, China, (Luo et al., 2016). However, some higher rates than in CUN were also registered (temperate Shisanling hydroelectric reservoir: 100 g C m^{-2} yr^{-1}, China, (Luo et al., 2016); US reservoirs: range 149 to 363 g C m^{-2} yr^{-1}, (Clow et al., 2015); temperate Lake Wohlen: 1,113 ± 482 g C m^{-2} yr^{-1}, Switzerland, (Sobek et al., 2012). According to the latest global estimate, an OC burial rate of 1,418 ± 2,761 g C m^{-2} yr^{-1} was reported for reservoirs (Mendonça et al., 2017). However, this high rate and variability is mainly due to small agricultural reservoirs (farm ponds), which are generally eutrophic systems that receive high sediment inputs from agriculture, resulting in high OC burial rates (Mendonça et al., 2017).

For reservoirs from warm climates, however, CUN has the highest OC burial recorded so far. CUN may receive enhanced sediment load from erosion, since it has undergone recent deforestation in the northwestern sub-catchments (Gunkel et al., 2003). However, CUN has a warm water column (mean surface water, 30°C; mean bottom water, 28°C), which implies high OC mineralization. Using the linear regression model (OC mineralization = 1.52 + 0.05 x temperature) by Cardoso et al., (2014) and the mean temperature of the bottom water in CUN, sediment OC mineralization was estimated at 325 g C m^{-2} yr^{-1}. Then, the total OC deposition rate onto the sediment (OC mineralization + OC burial) of CUN was 418 g C m^{-2} yr^{-1}, returning a OC burial efficiency of 22 % (OC burial efficiency = OC burial / OC deposition rate). In the warm-water lakes Kivu (Congo and Rwanda) and Kinneret (Israel), the OC burial efficiency was similar, and estimated at around 30 % (Sobek et al., 2009; Sobek et al., 2011). In the only warm-water reservoir where the OC burial efficiency has been determined thus far, the Macarenhas de Morais reservoir in the dry Cerrado climate of sub-tropical Brazil, the OC mineralization rate was much lower than in CUN (17 to 48 g C m^{-2} yr^{-1}) and the OC burial efficiency was 57%, almost three times higher than CUN (Mendonça et al., 2016). Since many factors affect the OC burial rate as well as burial efficiency, we cannot speculate in how far the values found in this study apply for other reservoirs in the Amazon region. Either way, the high OC burial rate in CUN in spite of high water temperature may be explained by a high OC deposition rate onto the

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sediment; a low OC burial efficiency allows high OC burial if only OC deposition onto the sediment is high enough.

The C:N ratio indicates that the sediment OC in CUN consists of a mixture of land-derived and internally-produced OC. The C: N ratio of the surface layers (n = 19) varied from 10.3 to 17 (average ± SD of 12.9 ± 2.1, **Table S4**), and the C:N ratios of phytoplankton are typically 6-9, for aquatic macrophytes >10 and for land plants >40 (Meyers and Ishiwatari, 1993; Grasset et al., 2019). Higher C:N ratios were observed in the dam area and at the river inflows (**Fig. 2**), which may indicate input from the highly productive watershed and thus the high load of land-derived OC to the sediment. These two areas also have an elevated sedimentation rate, as mentioned above (**Fig. 1**). Tropical rain forest is the dominating land cover in CUN, covering 90.8% of the watershed, followed by managed areas (8.9%) and water (0.3%) (**Table S5**). This may suggest that the high OC burial rates in CUN are related to a high OC input from the watershed; however, there was no strong relation between OC burial rate and C:N ratio (**Fig. S6A**). In addition, the middle section of the reservoir was characterized by relatively low C:N ratio, indicating a significant share of aquatic OC in the sediment (**Fig. 2**). Possibly, sewage input from riverside communities (represented as small black houses in **Fig. 2**) contributes with N to the reservoir and thus stimulates aquatic production, since a comparatively low C:N ratio was found near these settlements. However, also upstream of the settlements in Curuá-Una river, the sediment C:N ratio was relatively low; possibly, higher water transparency due to particle settling may stimulate aquatic productivity also in the absence of anthropogenic nutrient inputs. Also, even at low C:N ratios, OC burial rates were high (**Fig. S6A**). Hence, it is evident that internally-produced OC makes up an important contribution to the OC buried in the sediments of CUN. The source of buried OC has an important implication in terms of accounting the sediment carbon as

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a new sink or not (Prairie et al., 2017); however, our data do not allow to make a quantitative estimate of the share of the CUN sediment carbon stock that is of aquatic origin, and thus may be accountable as a new carbon sink resulting from river damming (Prairie et al., 2017).

Pore water CH_4 profiles and saturation

The overall mean CH_4 concentration in pore water from CUN was 1,729 ± 1,939 µM of CH_4 (mean ± SD) with similar averages during rising (1,700 ± 1,637 µM of CH_4, **Fig. S7**) and falling water (1,764 ± 2,243 µM of CH_4, **Fig. S7**) periods. At eight sites, we could make paired observations of CH_4 concentration in sediment pore water at both rising and falling periods (**Fig. 3**). These data show that the seasonal difference of CH_4 concentration in pore water was low and not significant (t-test, $t (14) = -0.08$, $p = 0.94$). Interestingly, the 2 of 8 sites with generally low CH_4 pore water concentration were low at both sampling occasions, indicating that there may be an important spatial component in sediment CH_4 production (**Fig. 3**, sites F24 x R16 and F57 x R39), which however was not related to the C:N ratio or OC burial rate at these sites.

Of the 25 pore water CH_4 profiles, 22 contained at least one sample with pore water CH_4 at >80% of saturation concentration; of the total of 386 pore water samples, 111 samples (29%) were >80% of CH_4 saturation concentration. This indicates a prevalence to form gas bubbles, and thus the possibility of CH_4 ebullition (**Table S6**). In accordance, sub-bottom data were for a large part of the reservoir not useable for identifying sub-bottom structures, because of a strong acoustic reflector in surficial sediment, presumably gas bubbles.

Pore water CH_4 saturation was higher in river inflow areas, especially in sampling sites in the Curuá-Una main river. The confluence of the rivers and the dam were also characterized by high pore water CH_4 (**Fig. 4**). Sites with higher OC burial rate, mainly inflow areas, also showed

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a tendency towards higher extent of CH_4 saturation (**Fig. S6C**). Hence, the CH_4 production in CUN sediments may rather be driven by the OC supply rate to anaerobic sediment layers (**Fig. S6**) than by the reactivity of the sediment OC (no association between the C:N ratio and the extent of CH_4 saturation; **Fig. S6B**). Links between high sedimentation rate and sediment CH_4 pore water concentration as well as CH_4 ebullition have been reported previously (Sobek et al., 2012; Maeck et al., 2013), and in addition, fresh land plant-derived organic matter such as leaves may fuel substantial CH_4 production at anoxic conditions (Grasset et al., 2018). This highlights that sediment accumulation bottoms close to river inflow areas can be prone to exhibit high CH_4 ebullition (DelSontro et al., 2011), not least because the shallow water column in inflow areas (**Fig. S5**) facilitates CH_4 bubble transport to the atmosphere.

In Mascarenhas de Morais reservoir (Brazil), 6 of 16 sites with pore water CH_4 concentration over the saturation threshold were found (Mendonça et al., 2016). In Lake Wohlen (Switzerland), 4 of 8 sites with pore water CH_4 concentration over the threshold were found (Sobek et al., 2012). Thus, CUN had a higher share of sites (22 of 25) with pore water CH_4 concentration over the saturation threshold. However, these studies used 100% saturation as a threshold, and are therefore not directly comparable. Using 100% saturation as a threshold in our data would only marginally lower the number of CH_4 pore water profiles with at least one sample above the saturation concentration (from 22 to 20 profiles of 25), and thus not affect the conclusion that the sediments in CUN are prone to form bubbles.

Conclusions

The comparatively high OC burial rate of the Amazonian CUN reservoir results probably from high OC deposition onto the sediment, since the warm water (28-30°C) implies a high

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sediment OC mineralization rate. The relatively low C:N ratio in large parts of the reservoir indicates a significant aquatic contribution to sediment OC burial. In some parts of the reservoir, particularly in the river inflow areas, sediments are probably a CH_4 source by ebullition. Given the planned expansion of hydropower dams in the Amazon region, future studies should quantify how OC burial and CH_4 emission may be affected by new Amazonian hydroelectric reservoirs.

Data availability. All the data used in this study can be found in the manuscript and in the Supplement.

Author contributions. GRQ, JRP, AI, RM, RV carried out the sampling campaings. GRQ processed the data. AI analyzed the samples. GRQ and JRP prepared the figures. SS, FR, RM designed the study. All authors contributed to interpreting data and writing the manuscript.

Competing interests. The authors declare that they have no conflict of interest.

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