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Methane and Carbon Dioxide Production and Emission Pathways in the Belowground and Draining Water Bodies of a Tropical Peatland Plantation Forest

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Abstract Peatlands are crucial yet vulnerable carbon stores. Here, we investigated carbon biogeochemical processes in tropical peatlands converted to plantations. We measured carbon dioxide (CO_2) and methane (CH_4) concentrations, stable isotope ratios and radiocarbon content in an experimental *Acacia crassicarpa* plantation in Sumatra, Indonesia. We found exceptionally high levels of dissolved organic carbon (DOC), CO_2, and CH_4 in porewater and drainage networks, indicating that *Acacia* plantations are carbon hotspots due to their high productivity and exposed carbon-dense substrates. Stable isotope models revealed that while CO_2 and CH_4 are produced belowground, CH_4 contribution was lower than in natural undrained peatlands. Radiocarbon analysis suggested that remobilized carbon contributed to the carbon pool, with a median age of ~470 years before present. These findings constrain the links between land-use, water table levels, and carbon dynamics, with implications for carbon management in plantation peatlands.

Plain Language Summary Peatlands keep a lot of carbon in their deep, wet soils, but their conversion to other land-uses leads to important quantities of carbon emitted to the atmosphere, contributing to global warming. In Southeast Asia, large areas of tropical peatlands have been converted to plantations. Yet, data on carbon production and emissions in these systems remain limited. This study measured the concentration, composition and age of carbon in the water and the soil in an experimental *Acacia* plantation site. We found high concentrations of, on average, century-old carbon in the water, similar to reports from other managed and degraded peatlands. However, in comparison to natural peatlands, we found that there was less methane (a strong greenhouse gas) proportional to carbon dioxide (the most common greenhouse gas) being produced in the studied plantations. Our findings show that it is important to carefully monitor and manage the carbon exchange in peatland plantations, to understand their environmental impact and discuss their role in the carbon cycle and the climate.

Key Points:

- This study is the first to report dissolved carbon concentrations, stable isotopes ratio & radiocarbon content from *Acacia* peat plantations
- Dissolved carbon concentrations in this study were among the highest reported, making *Acacia* peat plantations a carbon hotspot
- Oxic ecosystem respiration, rather than methanogenesis, was the main CO_2 source

Supporting Information:

Supporting Information may be found in the online version of this article.

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1. Introduction

Wetlands cover about 2% of Earth's land yet store a large amount of organic carbon (Blakemore, 2018; Fluet-Chouinard et al., 2023; Poulter et al., 2021) due to vegetation productivity surpassing slow organic matter decomposition in anoxic, waterlogged soils (Temmink et al., 2022). Peatlands, the predominant vegetated wetland type, are rapidly declining due to land-use changes (LUC; Fluet-Chouinard et al., 2023). Between 2001 and 2022, approximately 41% of Southeast Asia's peatland forests were impacted by land-use change (Sasmito et al., 2025). Conversion to tree plantations for fiberwood, rubber and palm oil was among the most common land-use changes (Sasmito et al., 2025). *Acacia* plantations, like other managed tree plantations on peatlands, are drained to maintain water table levels (WTLs) below root depth to support plant productivity, impacting carbon dioxide (CO_2) and methane (CH_4) production and release (Figure 1). WTL is managed using artificial drainage networks, including first-order channels (ditches), second-order channels (canals), and dams. Ditches are shallow and slow-moving, while canals are larger and deeper.

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WTL affects the redox environment, influencing peat organic matter (OM) production, decomposition and preservation (Figure 1). A shallower WTL creates anaerobic conditions near the surface, promoting dissolved organic carbon (DOC) production (Kellerman et al., 2014; Lynch et al., 2019), and OM degradation through acetoclastic methanogenesis (AM) and hydrogenotrophic methanogenesis (HM), resulting in CH_4 emissions typical of undisturbed peatlands (Holmes et al., 2015; Neubauer & Megonigal, 2022). Lowering WTL through drainage exposes upper peat layers to aerobic conditions, increasing CO_2 production through respiration and reducing CH_4 via methane oxidation (Figure 1). Conversely, raising WTLs (e.g., Hooijer et al., 2024; Parish et al., 2019) can decrease CO_2 emissions but increase CH_4 emissions (Evans et al., 2021). While WTL impacts on C-GHG emissions are well-documented (Carlson et al., 2015; Evans et al., 2021; Günther et al., 2020; Huang et al., 2021; Zou et al., 2022), subsurface biogeochemical processes in response to WTL shifts in tropical peatland plantations remain poorly understood.

Aquatic carbon dynamics in tropical peatlands remain uncertain due to a predominant focus on terrestrial GHG emissions (e.g., Deshmukh et al., 2020, 2021, 2023; Jauhiainen et al., 2008; Jauhiainen et al., 2012; Lupascu et al., 2020) and the exchange of peat-derived carbon and C-GHG within drainage networks (e.g., Martin et al., 2018; Moore et al., 2013; Nichols & Martin, 2021; Wit et al., 2018). The conceptual model in Figure 1 outlines pathways and $\delta^{13}C$ isotopic fractionations related to DOC, CO_2, and CH_4. Carbon input from peat porewaters to drainage networks may include particulate organic carbon, DOC, dissolved CO_2 and CH_4. In surface water, DOC can be mineralized via photochemical oxidation or bacterial metabolism, converting into CO_2, which may either evade the water surface or flow downstream (Somers et al., 2023). Similarly, CH_4 can be oxidized to CO_2 within the water column or released directly into the atmosphere. Because of its low solubility, CH_4 quickly evades or is released through ebullition from deeper water levels, while plants on vegetated surfaces may transport CH_4 emissions via their stems (Akhtar et al., 2021). Limited studies on carbon dynamics in ditches and canals draining managed tropical peatlands indicate high rates of organic carbon cycling and CH_4 production (Bowen et al., 2024; Deshmukh et al., 2020; Jauhiainen & Silvennoinen, 2012; Somers et al., 2023). Larger-scale assessments suggest modified peatland drainage networks could be significant CH_4 emissions hotspots globally (Peacock et al., 2021).

Understanding the factors controlling CH_4 and CO_2 production and transport pathways is crucial for evaluating how land-use change affects C-GHG emissions from peatlands. This study aimed to examine carbon and C-GHG production and transport pathways in the belowground and draining water bodies of an industrial short-rotation fiberwood (*Acacia crassicarpa*) plantation on peat, focusing on (*a*) the distribution, composition and age of dissolved carbon in an *Acacia* plantation; and (*b*) the influence of WTL on below-ground C-GHG production and emission pathways.

2. Study Site and Experimental Design

The study was conducted within a 647,000 ha ombrotrophic peatland converted into an industrial *Acacia* plantation in the Kampar Peninsula, Riau Province, Sumatra, Indonesia (Figure 2). The peatland, over 5,100 years old (Hapsari et al., 2022), experienced 2,707 mm of cumulative rainfall in 2022, 53% wetter than the 2014–2021 average (Deshmukh et al., 2021). September to November were the wettest months (>300 mm $month^{-1}$). January to February and May to August were the driest (<200 mm $month^{-1}$).

Within the experimental plantation, samples were collected in a 34-ha WTL manipulation experimental plot with a 0.52 m elevation gradient, causing southward water flow (Figure 2). This created a deeper WTL at the higher slope (Water Table Trial Deeper, WTT_Deeper) and a shallower WTL at the lower slope (WTT_Shallower). Despite efforts to maintain WTL near constant year-round by adjusting an outlet dam, variability occurred: mean WTLs were -0.23 ± 0.17 m for WTT_Shallower (negative values indicate water levels below the surface) and -0.67 ± 0.19 m for WTT_Deeper (Figure S1 in Supporting Information S1). While the experimental plot had specific WTLs and management, factors such as plant density, fertilization regime, silvicultural practices, and *Acacia* species were consistent with the rest of the plantation. The plot featured a network of narrow, shallow and partly shaded primary drainage channels (ditches) with slow-moving to stagnant water conveying water toward wider, navigable secondary channels (canals) mostly exposed to sunlight. During the driest period, ditches and canals are not surface-connected but remain linked through porewater transfers year-round.

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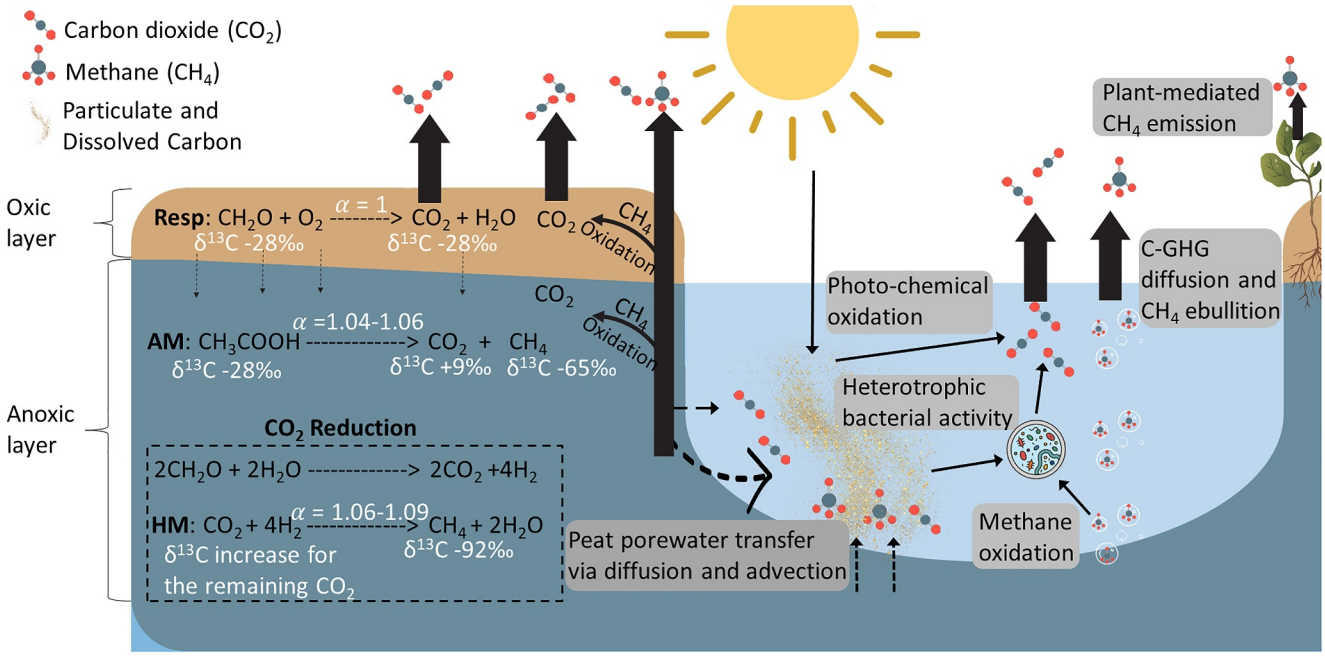

Figure 1. Conceptual model of biogeochemical processes in peat porewater and surface water. "Resp." = OM respiration, the main degradation pathway in the peat oxic layer. "AM" = acetoclastic methanogenesis, an anoxic pathway producing CO_2 and CH_4. "HM" = hydrogenotrophic methanogenesis, another anoxic pathway, part of CO_2 reduction, producing CO_2 and CH_4 (Corbett et al., 2013). Isotope fractionation factors (α) and expected isotopic compositions ($\delta^{13}C$) are from Holmes et al. (2015).

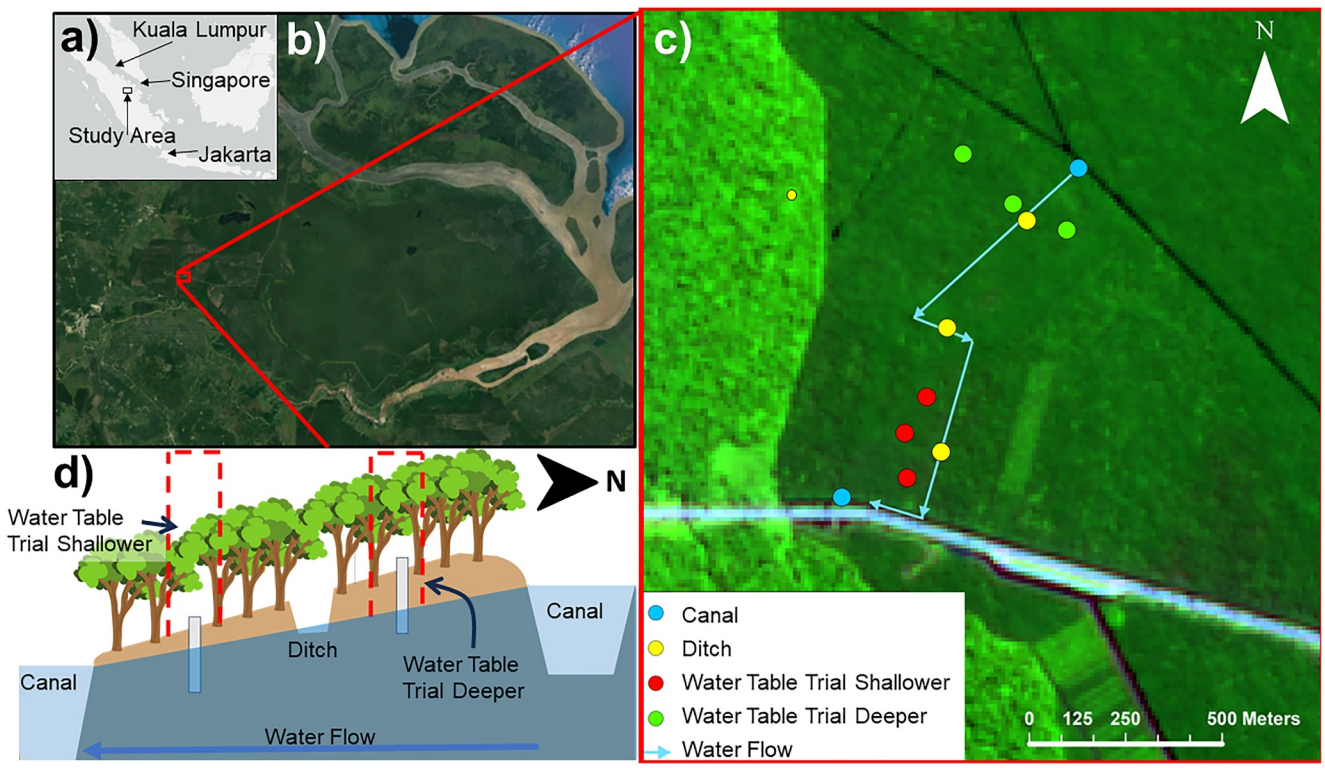

Figure 2. (a) Study area in the region and (b) in the Kampar Peninsula; (c) experimental site (0.516545°N; 102.107758°E) satellite imagery with the sampling stations along the North-to-South elevation gradient. (d) Conceptual model of the study site cross-section. Note that the water flow goes from North to South (right to left in the model).

3. Methods

3.1. Data Collection and Analysis

Porewater and surface water samples were collected in February, May, August, and November 2022. Triplicated porewater samples were taken from wells at WTT_Deeper and WTT_Shallower, while surface water samples were collected from ditches and canals banks (Figure 2).

For DOC concentration, water samples were filtered (45 µM cellulose acetate; Whatman, USA) and stored refrigerated in 15 mL PP tubes until analysis using a vario TOC cube analyzer (Elementar, Germany). Acidification was initially deemed unnecessary due to the natural acidity of the water (pH < 3.25). However, this resulted in an approximate 10% overestimation of DOC concentration as compared to the same samples acidified to pH < 2 from residual DIC (Figure S2 in Supporting Information S1). Therefore, a −10% correction was applied to non-acidified samples. Additional filtered water samples were collected in 250 mL Nalgene HDPE bottles and 40 mL glass vials for DO^{14}C analysis at the André E. Lalonde AMS Laboratory and δ^{13}C-DOC at the Ján Veizer Stable Isotope Laboratory (University of Ottawa, Canada).

Dissolved CO_2, CH_4, and their stable isotope composition (δ^{13}C-CO_2 and δ^{13}C-CH_4) were sampled using the headspace technique (e.g., Taillardat et al., 2022) and analyzed by cavity ring-down spectroscopy (G2201-i, Picarro Inc, USA). The pCO_2 and pCH_4 (ppm and µatm) were converted to concentrations (µM and mgC L^{-1}) based on water temperature and gas solubility coefficients (Goldenfum, 2011). The headspace technique was also used for dissolved ^{14}C-CO_2 following Garnett et al. (2016) and Murseli et al. (2019). Radiocarbon analyses were performed on an Ionplus AG MICADAS (Mini Carbon Dating System).

Statistical differences in dissolved carbon concentrations, δ^{13}C, and F^{14}C values across peat porewater sites (WTT_Shallower and WTT_Deeper) and surface waters were examined using non-parametric Kruskal-Wallis and Dunn-Bonferroni post-hoc tests. Statistical analyses and graphs were created in R version 4.4.0 (R Core Team, 2024).

3.2. Stable Isotope Mass Balance Models

Carbon stable isotope ratio (δ^{13}C) and variations in coexisting dissolved carbon forms offer process-level insights (e.g., Evans et al., 2014; Holmes et al., 2015; Moore et al., 2013; Throckmorton et al., 2015). The difference between δ^{13}C-CH_4 and δ^{13}C-CO_2 provides the isotope separation ε_c of CO_2–CH_4 that can identify the dominant methanogenic pathway between HM and AM (Figure 1; Whiticar, 1999). The apparent fractionation factors between CO_2 and CH_4 (α) were calculated using Equation 1:

$$\alpha = \frac{\delta^{13}\mathrm{C} - \mathrm{CO_2} + 1000}{\delta^{13}\mathrm{C} - \mathrm{CH_4} + 1000} \quad (1)$$

3.2.1. Estimating CO_2 Production From Methanogenesis and Respiration

δ^{13}C-CO_2 resulting from methanogenesis ($\delta^{13}C_{-CO_2-meth}$) can be calculated when δ^{13}C-CH_4 and δ^{13}C-DOC (or δ^{13}C-OM) are known (Equation 2) under two assumptions. First, AM produces equal amounts of CH_4 and CO_2. In contrast, HM produces CH_4 while consuming equimolar CO_2 but is part of the CO_2 reduction process. This CO_2 reduction originates from non-fractionating OM respiration and releases twice the amount of CO_2 over the amount of produced CH_4. As a result, when the chemical reactions of both methanogenesis pathways are fully accounted for, they both produce equimolar amounts of CH_4 and CO_2. However, these pathways do not yield similar δ^{13}C-CH_4 values (Figure 1). Second, measured δ^{13}C-CH_4 in peat porewaters approximate the CH_4 initially produced from methanogenesis (Corbett et al., 2013; Throckmorton et al., 2015).

$$\delta^{13}\mathrm{C}_{-\mathrm{CO_2}-\mathrm{meth}} = \frac{\left(\delta^{13}\mathrm{C} - \mathrm{DOC}\right) - (0.5).\left(\delta^{13}\mathrm{C} - \mathrm{CH_4}\right)}{0.5} \quad (2)$$

Non-methanogenic CO_2 production has the same δ^{13}C value as the OM substrate or, in this case, subsurface porewater δ^{13}C-DOC (Throckmorton et al., 2015). After determining $\delta^{13}C - CO_{2-meth}$ (Equation 3), the fraction

of CO_2 from either isotopic fractionating methanogenesis (fCO_{2-meth}) or non-fractionating OM respiration and fermentation ($fCO_{2-OM\ decay}$) is determined using Equations 3 and 4:

$$\left(\delta^{13}C_{-CO_2}\right) = \left(\delta^{13}C_{-DOC}\right) \cdot \left(fCO_{2-OM\ decay}\right) + \left(\delta^{13}C_{-CO_2-meth}\right) \cdot \left(fCO_{2-meth}\right) \quad (3)$$

and

$$fCO_{2-OM\ decay} + fCO_{2-meth} = 1 \quad (4)$$

Solving these allows the estimation of fCO_{2-meth} and $fCO_{2-OM\ decay}$ (Corbett et al., 2013; Throckmorton et al., 2015). Finally, the quantity of CO_2 produced via methanogenesis (CO_{2-meth}) can be determined using Equation 5:

$$fCO_{2-meth} \cdot CO_{2-porewater} = CO_{2-meth} \quad (5)$$

where $CO_{2-porewater}$ is the measured CO_2 concentration in porewater.

3.2.2. Estimating CH_4 Loss via Ebullition and Plant-Mediated Transport

Since methanogenesis yields equimolar amounts of CH_4 and CO_2, comparing the amount of CO_2 produced via methanogenesis ($CO_{2-meth} = CH_{4-meth}$) with measured CH_4 concentration ($CH_{4-measured}$) allows estimation of CH_4 lost through ebullition or oxidation ($CH_{4-trans}$) using Equation 6 (Corbett et al., 2013; Throckmorton et al., 2015).

$$CH_{4-trans} = CO_{2-meth} - CH_{4-measured} \quad (6)$$

3.3. Systematic Literature Review

A systematic review synthesized DOC, dissolved CO_2 and CH_4 concentrations from tropical peat porewater, ditches and canals. A literature search using the Scopus database on 17 April 2024 yielded used here from 50 independent studies and 397 individual study sites were used. Most studies did not provide comprehensive carbon values for all sampling types along the water continuum. A detailed description of the literature review methodology is provided in the Supporting Information S1.

4. Results and Discussion

4.1. Dissolved Carbon Concentrations

The dominant form of dissolved carbon in peat porewater was DOC (~76%; median = 127.1 mgC L^{-1}; range: 104.6 to 144.0 mgC L^{-1}), followed by dissolved CO_2 (~24%; median = 39.6 mgC L^{-1}; range: 20.0 to 62.6 mgC L^{-1}) while dissolved CH_4 made up less than 1%, with a median of 1.4 mgC L^{-1} (range: 0.1 to 8.3 mgC L^{-1}). There were no significant differences in dissolved carbon concentration between WTT_Shallower compared to WTT_Deeper (Figures 3a–3c). In surface water (ditches and canals), DOC comprised over 92% of total dissolved carbon, with dissolved CO_2 at 8%, and CH_4 was negligible. Total dissolved carbon (DOC + CO_2 + CH_4) was higher in ditches than in canals, with statistical significance for DOC and CO_2, but not CH_4 (Figures 3a–3c). Dissolved CO_2 and CH_4 levels were 4 and 92 times lower, respectively, in surface water than in peat porewater, while DOC remained within the same order of magnitude (Figures 3a–3c). No clear seasonal trend emerged between the different forms (Figure S3 in Supporting Information S1), likely due to consistent warm, humid conditions throughout the year.

DOC concentrations at our study site were in the highest range reported from tropical peatland settings (Figure 4a). While average DOC concentrations in peatland canals across the tropics are ~46 mgC L^{-1}, we measured DOC concentrations consistently >100 mgC L^{-1} (Figure 3a). Previously, the highest values (>65 mgC L^{-1}) were from an undisturbed peat swamp forest (Moore et al., 2013), a logged one (Waldron et al., 2019), an oil palm plantation (Waldron et al., 2019), and a Sago palm plantation (Miyamoto et al., 2009). Two explanations were considered. First, plantation trees are highly productive, likely releasing substantial DOC through root

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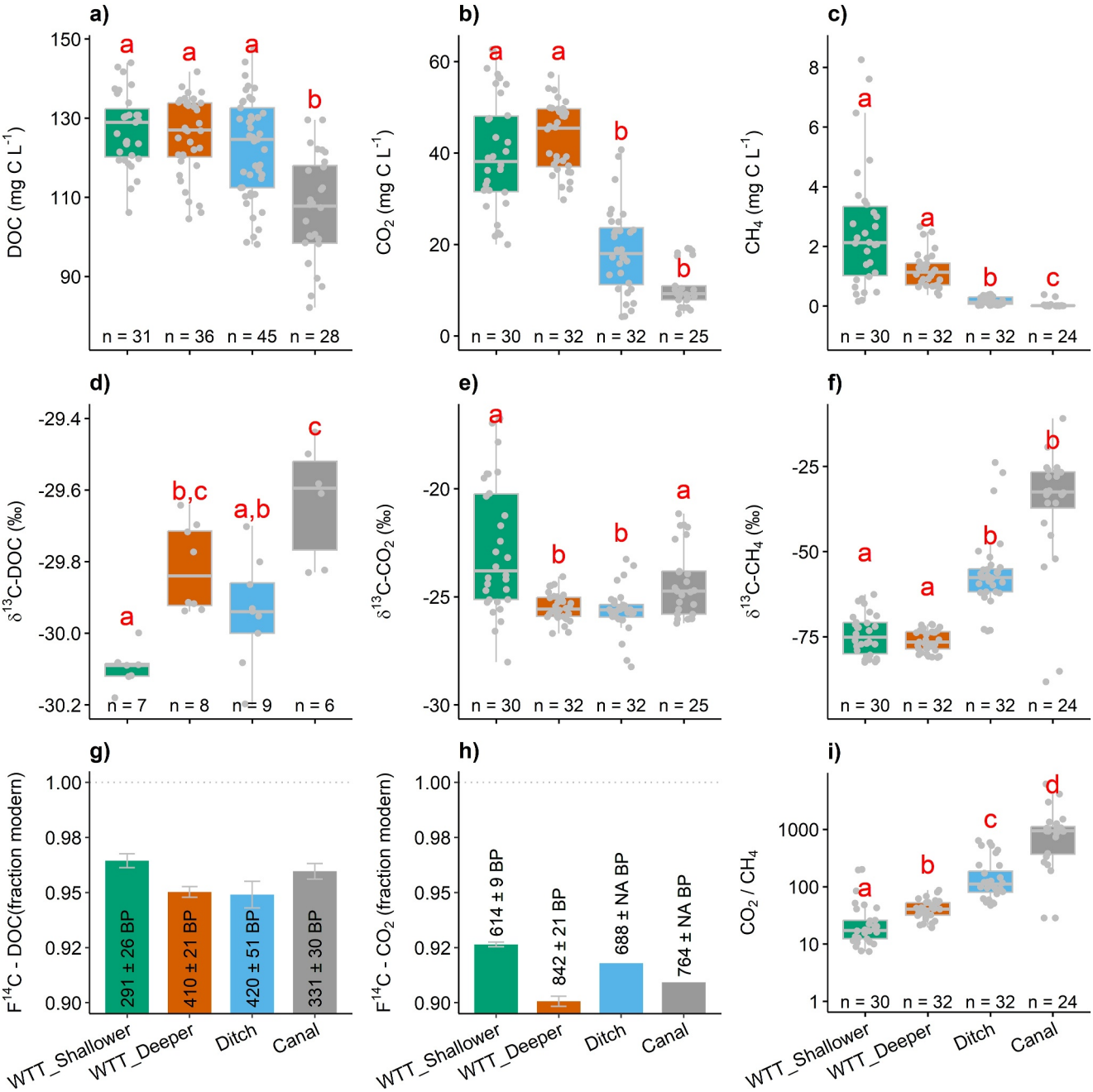

Figure 3. Dissolved carbon concentrations (a–c, i) $\delta^{13}C$ (d–f) and $F^{14}C$ values (g, h) in peat porewater (WTT_Shallower, WTT_Deeper), ditch and canal. Boxplot medians (thick lines), quartile (box limits), whiskers (1.5 times the interquartile range (IQR)), and data points (dots) are shown. Different lowercase red letters above whiskers indicate significant differences ($p < 0.05$; e.g., *a* and *a* are statistically the same; *a* and *b* are statistically different) between groups. Note the exponential *y*-axis in panel i.

exudation and leaching from fresh litter (Deshmukh et al., 2020, 2023). Second, the ditch conditions in plantations may prevent DOC degradation. About 30% of the DOC in peatland canals may be degraded through photooxidation (Bowen et al., 2024). Since the studied ditches are slow-moving, shallow and partly shaded (Figure 2d), DOC may remain undegraded until reaching wider, deeper canals downstream where incoming radiation is higher (Figure 3a). Our study is only the fourth to report total carbon concentrations from ditches in tropical peatlands (Cook et al., 2018; Manning et al., 2019; Moore et al., 2013), although the importance of ditches on carbon cycling and C-GHG emissions is globally acknowledged (Peacock et al., 2021). Therefore, the lack of data from

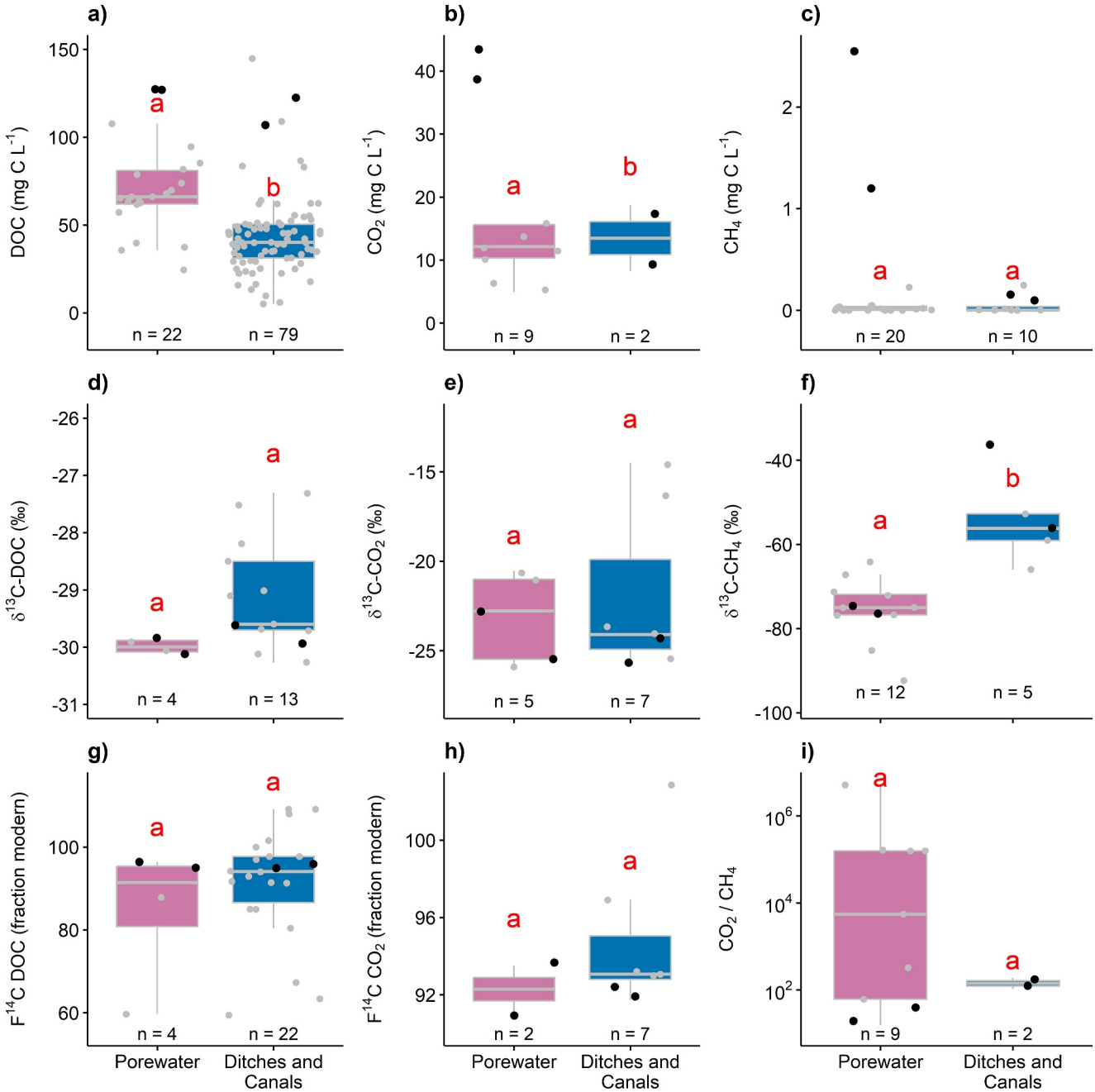

Figure 4. Dissolved carbon concentrations (a–c), $\delta^{13}C$ (d–f), F^{14} C values (g, h) and CO_2/CH_4 ratio (i) in peat porewater, ditches and canals from our systematic review. Boxplots show medians (thick lines), quartiles (box limits), whiskers (1.5x IQR), and individual data points from the literature (gray dots) and our study (black dots). Different lowercase red letters above whiskers indicate significant differences ($p < 0.05$) between groups. Note the exponential *y*-axis on panel (i).

ditches in managed tropical peatlands may be a missing link in understanding peat-derived carbon processes along the aquatic continuum (Evans & Taillardat, 2024).

Few studies have reported dissolved CO_2 and CH_4 concentrations in tropical peatlands (Figures 4b and 4c). Our systematic review found no studies on dissolved CO_2 and only two on dissolved CH_4 in canals draining peatland, with CH_4 concentrations ranging from 0.5 to 248 μgCL^{-1} (Somers et al., 2023; Waldron et al., 2019). Comparisons with global-scale data sets covering wetlands and water bodies more broadly suggest that dissolved CO_2 and CH_4 at our study site are among the highest reported; Liu et al. (2022) reported global dissolved CO_2 values in streams and rivers ranging from 34 to 27,205 µatm, while tropical values ranged from 141 to 22,899 µatm, well

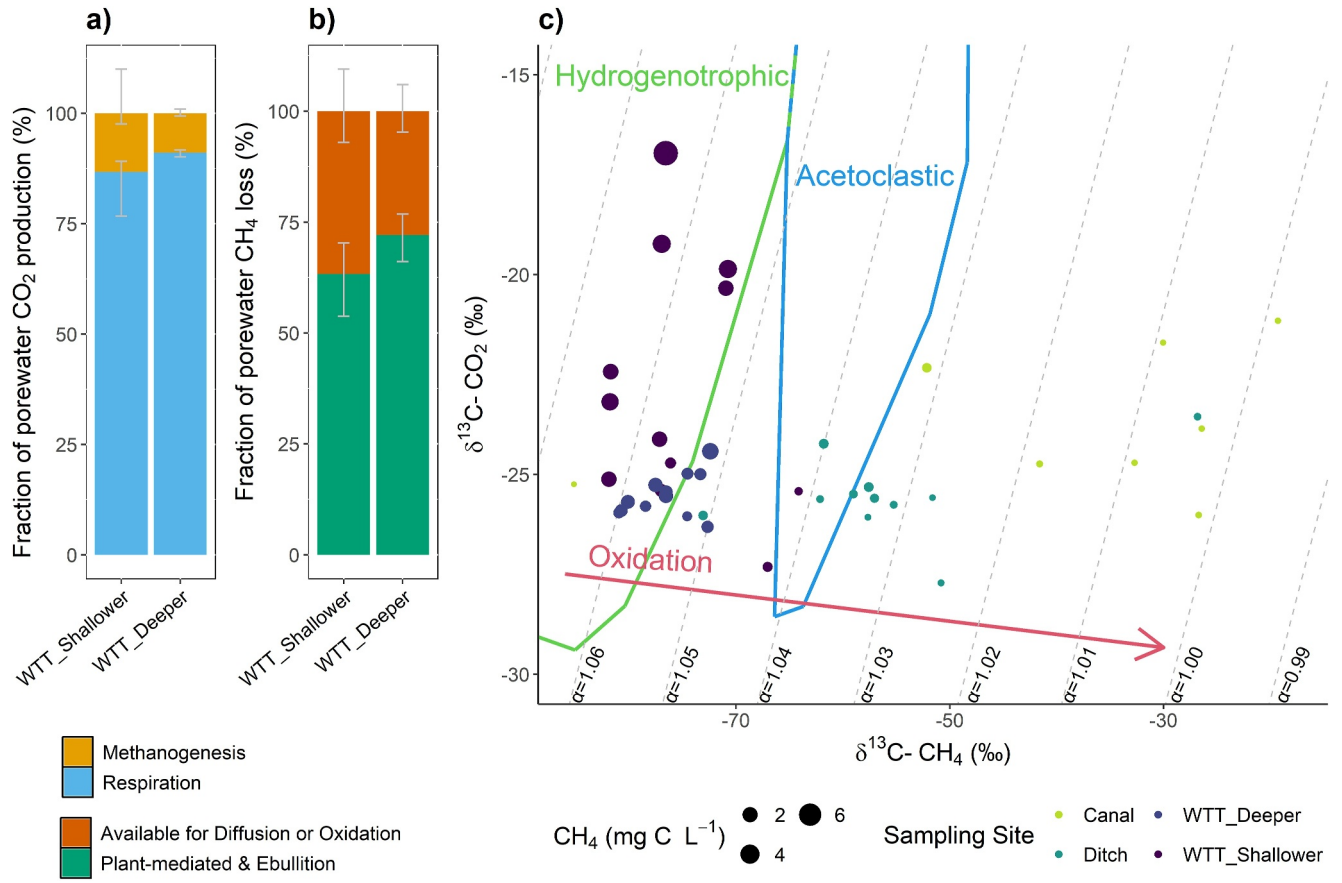

Figure 5. (a) Results from the stable isotope mixing models reporting the contribution of methanogenesis and ecosystem respiration to dissolved CO_2 production. (b) Proportion of CH_4 loss pathways, including diffusion or oxidation versus plant-mediated and ebullition pathways. Bars represent median values, with error bars indicating the first (Q1) and third quartiles (Q3). (c) Crossplot $\delta^{13}C$ values in porewaters from WTT_Shallower and WTT_Deeper, ditch and canal. Dot size reflects CH_4 concentration. The oxidation line is from Knorr et al. (2009). The hydrogenotrophic and acetoclastic areas are from Negandhi et al. (2019).

below our measurements (10,984–107,018 µatm or 4.20–40.71 mgC L^{-1}). Similarly, our CH_4 levels are among the highest in the Global River Methane Database (GRiMeDB; Stanley et al. (2023)), event though tropical systems are underrepresented in this database. Although peatland drainage minimizes terrestrial CH_4 emissions (Evans et al., 2021; Günther et al., 2020; Huang et al., 2021; Zou et al., 2022), our results confirm that drainage contributes to additional C-GHG emissions via the aquatic pathway (Deshmukh et al., 2020; Peacock et al., 2021). Further measurements of dissolved CO_2 and CH_4 concentrations and fluxes from peatland drainage networks are necessary to incorporate them into global carbon assessments (e.g., Rocher-ros et al., 2023; Rosentreter et al., 2021).

Radiocarbon analysis showed $F^{14}C$ values between 0.90 and 0.97, suggesting carbon predominantly fixed before 1955 CE (Figures 3g and 3h). DOC contained significantly more ^{14}C-enriched samples than CO_2, but the indicative mean ages for both were ~470 years before present. Our results align with previous peatland studies, where $F^{14}C$-CO_2 is often lower than $F^{14}C$ -DOC (Figures 4g and 4h) presumably due to methanogenesis producing a fraction of the total CO_2 from deeper, older anaerobic layers compared to respiration in the aerobic upper layer (Dean et al., 2023). Another explanation could be the different physical properties between the DOC and CO_2. DOC can only leave the peat via the drainage system, whereas younger CO_2 produced near the peat surface may escape to the atmosphere. There was no substantial difference in mean $F^{14}C$ value between WTT_Shallower and WTT_Deeper (Figures 3g and 3h). These results support the rationale that deeper WTLs in degraded and managed peatlands expose older OM to decomposition or dissolution (Cook et al., 2018; Evans et al., 2014; Moore et al., 2013), despite the high *Acacia* productivity in our case.

4.2. Water Level Influences Below-Ground Gas Production Magnitude and Emission Pathways

The $\delta^{13}C$ values measured at our site (Figures 4d–4f) are consistent with existing data for tropical peatlands. The porewater $\delta^{13}C$-CO_2 (~−23‰) is similar to values from forested areas with C_3-derived OM degradation (Campeau et al., 2017a, 2017b; Hutchins et al., 2020) and a tropical wetland in Panama (Holmes et al., 2015). Using an isotope mass balance model (Equations 3 and 4), our results indicate that ecosystem respiration, a non-fractionating pathway, was the main source of CO_2 at both sites (Figure 5a). The predominance of respiration (>80%) contrasts with undisturbed boreal peatlands, where most dissolved CO_2 in porewater is from methanogenesis, indicated by a median porewater $\delta^{13}C$-CO_2 of −3.8‰ (Taillardat et al., 2022) or $\delta^{13}C$-DIC of −4.6‰ (Campeau et al., 2018). The importance of ecosystem respiration can be explained by increasing oxic layer depth from drainage and the year-round warm, humid conditions leading to respiration rates greater than those at higher latitudes.

The significantly lower $\delta^{13}C$-CO_2 and CO_2/CH_4 ratio at WTT_Shallower compared to WTT_Deeper (Figures 3e and 3i), support the hypothesis that WTL influences belowground gas production. According to our mass balance model, methanogenesis was proportionally more important at WTT_Shallower, even though >80% of CO_2 was from oxic respiration (Figure 5a). Increased hypoxia suitable for methanogenesis and reduced methanotrophy are expected with a shallower WTL (Dean et al., 2018). Access to fresher, more labile OM may further stimulate degradation in upper peat layers, explaining higher CO_2 and CH_4 concentrations at WTT_Shallower.

The very negative $\delta^{13}C$-CH_4 (<−70‰) at both WTTs suggests that methanogenesis was predominantly through the HM pathway (Figure 5c), which is consistent with undisturbed tropical peatlands (Holmes et al., 2015). Our analysis of CH_4 loss pathways (Equation 6) suggests that most dissolved CH_4 in peat porewater was lost via ebullition and plant-mediated transport rather than being available for diffusion, oxidation, or lateral export to ditches, with little variation between WTTs (Figure 5b). This aligns with findings from higher latitudes (Corbett et al., 2013; Throckmorton et al., 2015). The under-documented importance of ebullition and plant-mediated emissions could potentially explain global CH_4 budget discrepancies (Saunois et al., 2020) and requires further investigations (Bodmer et al., 2023).

5. Conclusion

In reporting among the highest published value for DOC, dissolved CO_2, and CH_4 concentrations, our study highlights that *Acacia* plantations on tropical peat are significant carbon production, transformation and emission hotspots. This is due to a combination of high productivity and carbon-dense substrates exposed to remobilization, combined factors that are also found on other fast-growing tree plantations on peat. Our findings also suggest that within the experimental forest plantation, WTL influenced carbon-GHG production, with higher dissolved CH_4 concentrations relative to CO_2 in areas where the WTL was shallower, where surrounding organic matter was younger and potentially more labile. Findings from this study are essential to understanding carbon cycling in *Acacia* plantations on peat and developing water management practices that can reduce emissions while maintaining commercial productivity.

Data Availability Statement

Data and code to reproduce the analysis, results and figures are available in the Zenodo repository (Taillardat, 2025; Taillardat et al., 2025).

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