Surface DOC Fuels Belowground Respiration in a Neotropical Peatland

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Tropical peatlands are vital to global carbon (C) cycling, yet the factors influencing carbon dioxide (CO_2) and methane (CH_4) emissions, particularly from below the surface, remain poorly understood. This study investigated the sources and processes governing C emissions from deep layers in a Neotropical peatland along Panama's Caribbean coast. We hypothesized that: 1) surface-derived organic matter transported down through the soil profile is the primary C source for respiration at depth, and 2) high lignin content results in hydrogenotrophic methanogenesis as the predominant CH_4 production pathway throughout the profile.

To test these hypotheses, we used radiocarbon isotopes to determine whether deep CO_2 and CH_4 production originates from modern organic material or ancient peat, and stable C isotopes to identify the dominant CH_4 production pathway. Peat organic chemistry was analyzed using 13^{13}13C solid-state nuclear magnetic resonance spectroscopy (NMR). Our findings reveal that deep peat respiration products shared radiocarbon signatures more similar to surface dissolved organic carbon (DOC) than to deep solid peat, despite stable peat chemistry from surface to deeper layers. Radiocarbon dating indicated that deep peat at the study sites ranged from 1200 to 1800 years BP. These results suggest that surface-derived C, likely transported as DOC, is the primary source of gas production at depth.

Carbohydrate content did not vary significantly with depth, whereas lignin—the dominant compound, comprising 55-70% of C—tended to increase. This pattern suggests preferential retention of lignin rather than selective decomposition of carbohydrates. Stable isotope signatures of the respiration products confirmed that hydrogenotrophic methanogenesis, rather than acetoclastic methanogenesis, is the primary pathway for CH_4 production across the peat profile. These findings highlight that even typically decomposition-prone compounds, such as carbohydrates, are preserved in these deep tropical peat layers, underscoring the role of anaerobic, waterlogged conditions in conserving C within tropical peatlands.