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Effects of microtopography, root exudates analogues and temperature variation on CO2 and CH4 production from fire-degraded tropical peat

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Despite being an important terrestrial carbon (C) reserve, tropical peatlands (TP) have been heavily degraded through extensive drainage and fire, to an extent where degraded TP occupies one-tenth of the total peatland area in Southeast Asia (as in 2015). Consequently, repeated fires along with frequent flooding can alter the microtopography, vegetation composition as well as higher diurnal temperature variation due to open canopy, where each is known to influence C dynamics. However, assessing the importance of all these variables on-site can be challenging due to difficult site conditions; hence an incubation experiment approach may provide more useful insights in disentangling the complex interplay of these important variables in regulating GHG (CO_2 and CH_4) production and emissions from fire-degraded tropical peatland areas. Therefore, we conducted an incubation study to investigate the interactions of microtopography (creating water-saturation conditions: mesic, flooded oxic, and anoxic), labile C inputs (in form of root exudate secretion from ferns and sedges), as well as on-site diurnal temperature variation in regulating CO_2 and CH_4 production from fire-degraded tropical peat.

We found that CO_2 and CH_4 production significantly varied among treatments and were strongly regulated by microtopography, labile C inputs, and temperature variation. Mesic (oxic) treatments acted as a strong source of CO_2 (230.4 ± 29 $\mu gCO_2\ g^{-1}\ hr^{-1}$) and mild sink for CH_4 (-5.6 ± 0.2 $ngCH_4\ g^{-1}\ hr^{-1}$) compared to anoxic treatments acting as a mild source of CO_2 (61.3 ± 6.2 $\mu gCO_2\ g^{-1}\ hr^{-1}$) and strong source of CH_4 (591.9 ± 112.1 $ngCH_4\ g^{-1}\ hr^{-1}$). The addition of labile C enhanced both the CO_2 and CH_4 production irrespective of the treatment conditions, whereas the effect of diurnal temperature variation was clearly pronounced in mesic (for CO_2) and anoxic (for CH_4) conditions. Q_{10} values for both CO_2 and CH_4 production varied significantly with higher values for CO_2 in mesic treatments (1.21 ± 0.28) and higher for CH_4 in anoxic treatments (1.56 ± 0.35). We also observed a gradient across conditions, where flooded oxic treatments showed in-between values both for CO_2 and CH_4 production and temperature sensitivity, further reflecting the importance of on-site peat water-saturation in regulating the GHG production and emission from the fire degraded tropical peatland areas.

Overall, these findings highlight how the water-saturation conditions due to microtopographic variation in peat surface, quality, and quantity of labile C secreted from plant communities and temperature variation during a day can influence the GHGs production rates from the fire degraded tropical peat. More importantly, given the current state and extent of degraded tropical peatland areas and future climate and land-use changes as well as frequent fire episodes in the region, our results demonstrate the increasing trend in GHG production from the fire-degraded tropical peatlands in Southeast Asia.