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Diversifying understory vegetation and riparian restoration as ecological management options to regulate greenhouse gas fluxes in oil palm plantations

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Oil palm (OP) plantations have replaced large areas of forest in the tropical landscape of Southeast Asia and are major emitters of greenhouse gases (GHGs). However, within established plantations there are management options which may reduce these emissions, including altered management practices within plantations and restoring forest within the landscape. Managing the vegetation within and around plantations could potentially minimise environmental damage and maximise co-benefits such as soil protection, pest control and support for biodiversity. Such practices include relaxed management, passive restoration, and active restoration. The impact of these management practices is uncertain, and there is a real need for an evidence-base to guide improvements in the environmental sustainability of OP management.

Here we present GHG fluxes from two long-term experiments as part of 'The Biodiversity and Ecosystem Function in Tropical Agriculture' (BEFTA) Project. The first experiment is investigating the impact of three alternative understory management treatments on biodiversity, ecosystem functioning and yield in Sumatra, Indonesia:

- Normal biodiversity complexity: standard industry practice, intermediate level of herbicide use in harvest circles around the palms.
- Reduced biodiversity complexity: spraying/removing all understory vegetation with herbicides.
- Enhanced biodiversity complexity: reduced-input management with no herbicide application and limited understory cutting.

The second experiment focusses on riparian restoration options ('Riparian Ecosystem Restoration in Tropical Agriculture' (RERTA) Project). The experimental site began as a mature OP plantation, followed by felling in April 2019 and replanting and riparian restoration in October 2019. Four management strategies were applied on both sides of a river to create 50 m riparian buffers, 400 m in length:

- A control treatment of no restoration, the removal of mature OP and replanting of young OP to the river margin.
- Passive restoration: Little to no agricultural management of mature OP.
- Active restoration A: Clearance of mature OP and enrichment planting with native forest trees.
- Active restoration B: Little or no agricultural management of mature OP and additional enrichment planting with native forest trees.

For both experiments, we measured the GHGs nitrous oxide (N_2O), methane (CH_4) and ecosystem respiration/carbon dioxide (CO_2) from static chambers and analysis by gas chromatography (GC-μECD/FID). Additionally, meteorological and basic soil parameters were measured as potential variables or drivers of measured fluxes that might be greater than any 'treatment' or ecological management effect. Measurements were carried out monthly from the understory treatments, taken from 54 static chambers for the duration of one year starting in October 2018. For the riparian restoration project, monthly background measurements were taken between January and April 2019 and then approximately monthly after replanting from 6 chambers in each riparian treatment and 16 in the actual OP plantation resulting in 40 chambers in total.

We investigated whether the observed ecological benefits of alternative management and restoration options such as introducing native tree species in riparian buffers and allowing the natural regrowth of understory in plantations may be associated with an additional or reduced GHG burden; thereby assessing the overall environmental impact.