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Long-term impacts of oil palm cultivation on soil carbon dynamics and biogeochemical soil properties following pasture conversion in Colombia

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Contrasting land use change (LUC) trajectories have been identified in the widespread expansion of oil palm (OP) plantations. However, most of the literature to date focuses on the impacts of extensive deforestation for the expansion of these perennial plantations. Additionally, the majority of LUC research for OP expansion until now has been focus on the effects of LUC after 25-30 years (time corresponding to one OP commercial cycle), and far less research has been undertaken to quantify the impacts of OP cultivation on soil properties over longer timescales. On the other hand, the conversion of pastures into OP plantations has been proposed as an alternative to the expansion of OP cultivation in forest areas, though its impacts on total ecosystem C stocks and soil biogeochemical properties have not been studied yet. In Colombia, pasture conversion into OP plantations is an important LUC type an it represents an opportunity to investigate important C-cycling processes that remains unclear in LUC to OP. We conducted the first study that seeks to quantify the long-term effects of OP cultivation following pasture conversion on soil C storage, dynamics and biogeochemical properties using a chronosequence approach. Soils were sampled in the eastern zone of Colombia from pasture reference sites and OP plantations ranging from 12 to 56 years old, down to 50 cm. Our results indicate a significant reduction in soil organic carbon (SOC) stocks over two rotation cycles. The gradual decrease in δ13C enrichment allowed us to trace the origin of soil organic matter (SOM). The accumulation rate of OP-derived C was unable to offset the losses of the original SOC. This resulted in net SOC losses of about 1 Mg C ha-1 yr-1 over the two rotation cycles. By the end of the first and second OP cycle, the proportion of SOC derived from OP was of about 28% and 48%, respectively. Carbon renewal was faster in upper soil layers, but also occurred down to 50 cm in the oldest plantations. Despite the observed decline in SOC stocks, soil chemical fertility increased over time (due to heavy fertilizer use). The depletion of SOC stocks in heavily weathered soils subjected to long-term intensive agriculture implies heavy reliance on external fertilizer inputs to sustain soil fertility. Further, we found greater N stocks in the subsoil compared to the topsoil, indicating loss of soil's nutrient retention capacity due to SOC depletion. At the ecosystem level, after accounting for the time-averaged aboveground C stocks in OP plantation life cycle, the transition of pastures into OP does not lead to net C loss. Soil biological properties including microbial biomass C, basal respiration and dissolved organic C decreased after LUC. We conclude that in contrast to the conversion of forest into OP, pasture conversion into OP has good potential for C sequestration. Nonetheless, it can also encompass important trade-offs between soil biogeochemical properties. In OP agriculture, it is necessary to find alternative nutrient sources in order to replenish SOM and maintain soil fertility thereby reducing fertilizer use.