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No signs of soil organic matter accumulation and of changes in nutrient (N-P) limitation during tropical secondary forest succession in the wet tropics of Southwest Costa Rica

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Secondary forests comprise large tracts of the tropical land area, due to ongoing changes in land-use, including selective logging and agricultural land abandonment. Recent meta-analyses demonstrated that temperature and precipitation are key drivers of forest ecosystem recovery, particularly of soil organic carbon (SOC) build-up, where losses of SOC after deforestation and cultivation (and its recovery after abandonment) were largest in the wet tropical lowlands. However, wet lowland tropical chronosequences are strongly underrepresented (<10% of all data with MAP >4000 mm) and the large variance in this group may be explained by soil type and soil nutrients. Moreover strong effects of (and changes in) nutrient limitation, with an intermittent change from P to N limitation of plant production in young tropical secondary forests, have been identified in a few studies.
For this study we established a tropical secondary forest chronosequence, identifying old pastures (>40 years), young to old secondary forests (1-55 years) and old-growth forests based on aerial photographs and satellite images dating from the 1960s to the 2010s in SW Costa Rica, a region where mean annual temperature is 27°C and mean annual precipitation between 5000 and 6000 mm. Soil samples were taken incrementally to 45 cm depth, sieved and soils and roots collected and analysed.
Bulk density decreased and SOC content increased from pastures to secondary forests and old-growth forests, with the net effect on soil C stocks (between 63 and 92 Mg ha-1 (0-45 cm)) being neutral. SOC stocks were generally high, due to high fine root densities and associated high root inputs to mineral soils in pastures and forests. SOC showed relatively slow turnover times, based on root and soil delta13C values, with turnover times of 120 and 210 years in topsoils and subsoils, indicating strong stabilization of SOM due to mineral binding and high aggregate stability (>80%). At the same time we found no change in soil N and P availability, but high microbial N:P ratios and very low Olsen P, indicating P limitation across the whole chronosequence due to strong chemical soil weathering and P fixation to Fe and Al oxides. In contrast we found an intermittent decrease in soil pH and in base saturation from pastures to young secondary forests and later increases towards old-growth forests. This dip in base saturation is most likely related to the high demand for base cations during rapid biomass build-up (particularly Ca-rich wood) during early secondary succession which is later counterbalanced by cation pumping by deep rooting trees from cation-rich deep soil layers and redistribution to the topsoils through litterfall and root turnover. The presented results on SOM and nutrient dynamics will be set in relation to aboveground biomass recovery at the same sites, and compared to other forest chronosequences in the tropics, to better understand climate and nutrient effects on the recovery of tropical forests after abandonment of agricultural land.