Soil carbon balance following conversion of grassland to oil palm

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Introduction

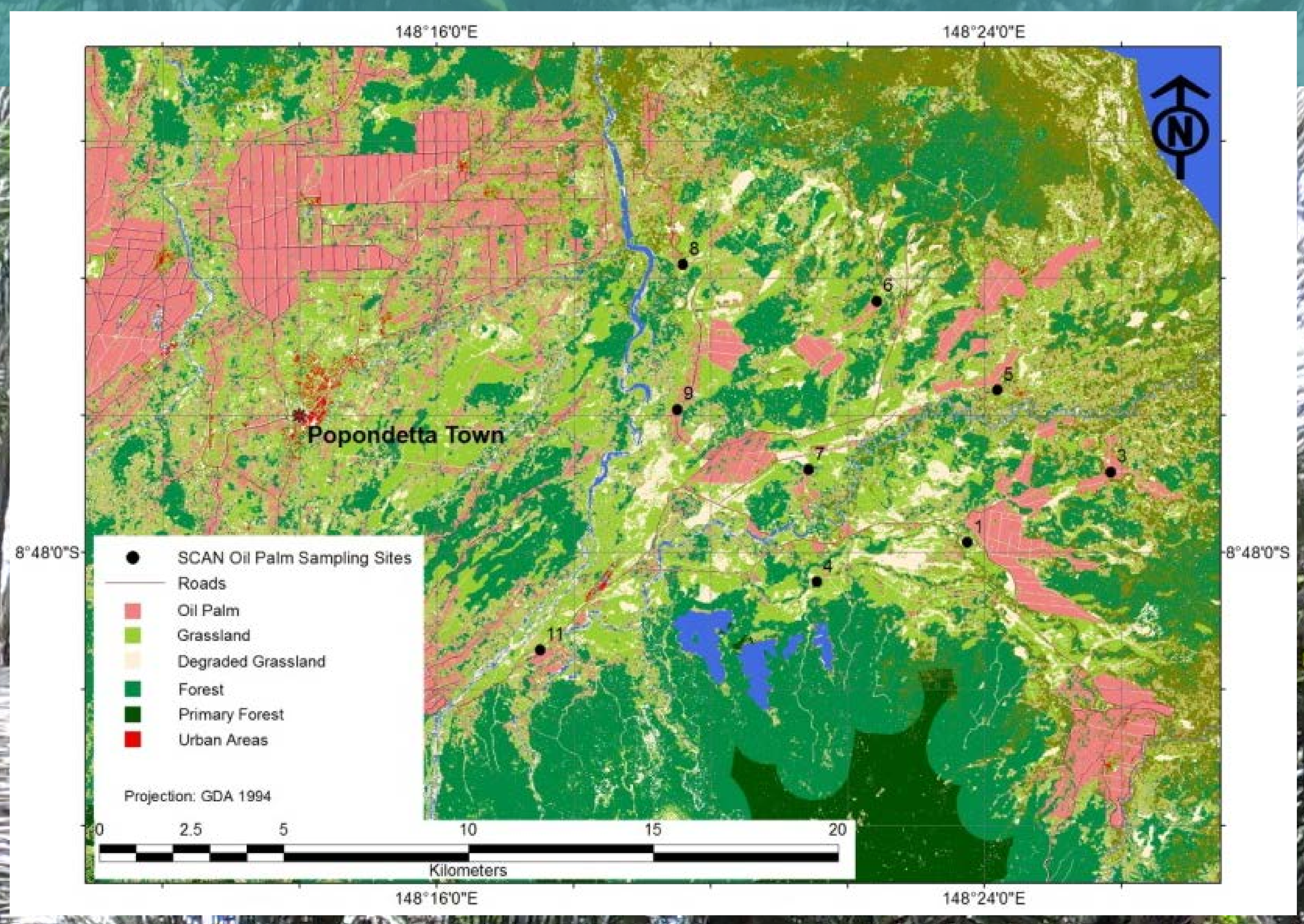
Oil palm is an important crop of the humid tropics, with a planted area of 12 million ha, growing at around 400,000 ha per year. Information of the carbon footprint of palm oil production is needed because oil palm often replaces tropical forests containing large stocks of carbon, and because palm oil is increasingly used to produce biofuels. Because of this interest a number of greenhouse gas budgets of oil palm operations have been produced (Syahrinudin 2005; Germer et al. 2008; Gibbs et al. 2008; Reijnders et al. 2008; Wicke et al. 2008; Chase and Henson 2010) but information about soil organic carbon (SOC) changes is important to strengthen these budgets.

There is limited information of the changes to SOC stocks under oil palm. No studies have calculated SOC losses over the life of a plantation including the initial land use change and no studies have measured changes in SOC upon conversion of grassland to oil palm. Oil palm plantings on grasslands provide an opportunity to use stable carbon isotope analysis to investigate changes to SOC.

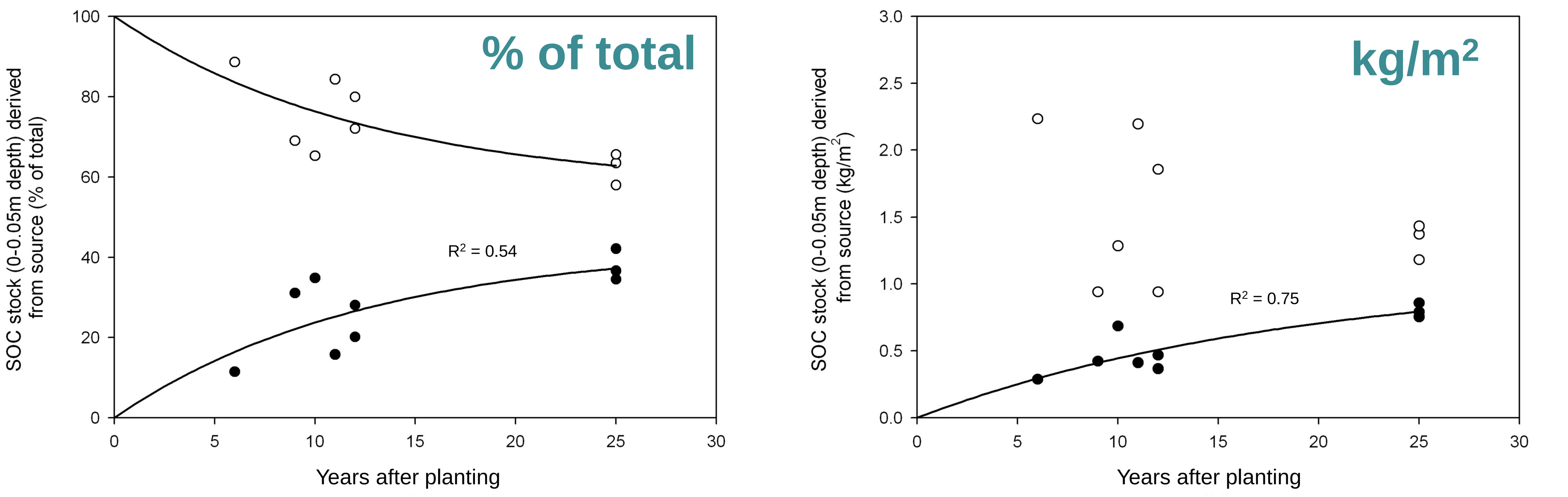
The aims of this study were to :

1) Measure SOC stocks in several oil palm plantations in Popondetta, Papua New Guinea (PNG).
2) Determine the rate of accumulation of SOC from oil palm inputs and the rate of disappearance of the existing SOC stock (including during the initial conversion from original vegetation).
3) Identify whether soil in oil palm plantations established on tropical grasslands in PNG is a source or sink of atmospheric carbon dioxide.

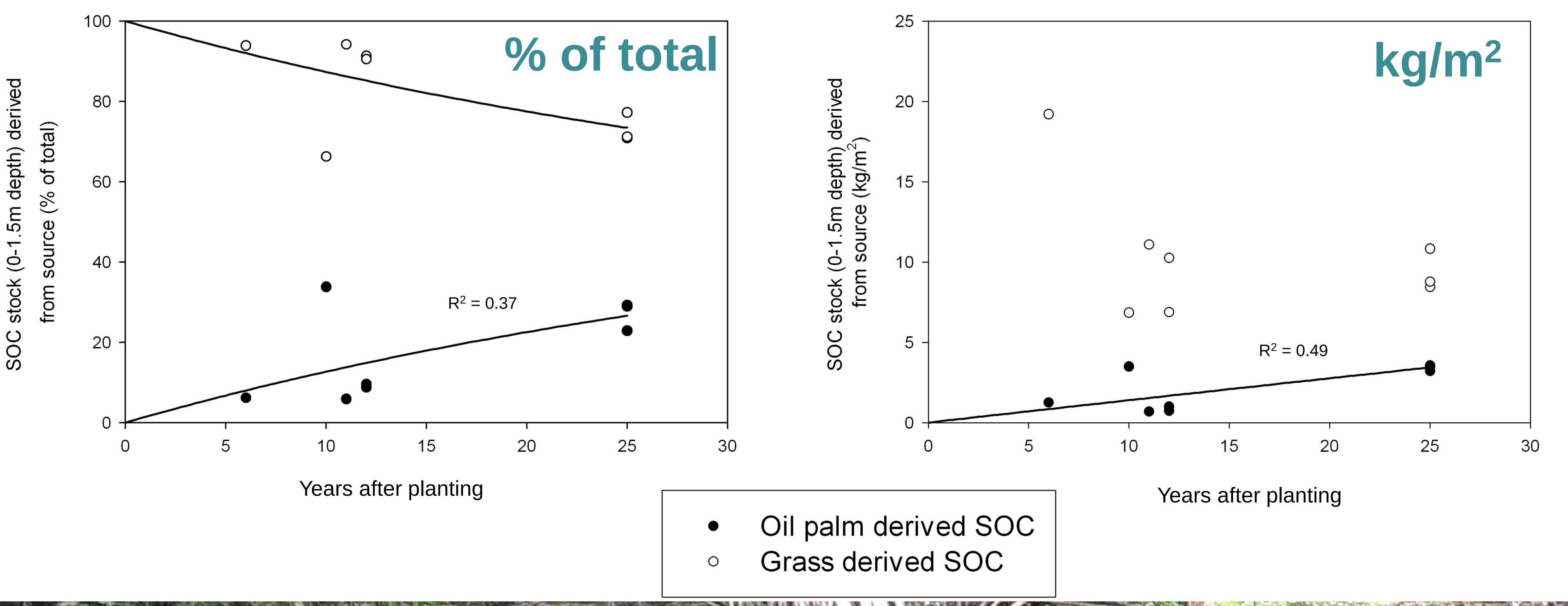
Study Sites



Soil organic carbon at 0-0.05 m depth



Soil organic carbon at 0-1.5 m depth



Experimental Design

- The study took place at 9 sites on young volcanic ash soils in Popondetta, PNG.
- At each site, soil samples were taken from a smallholder oil palm plantation that had been planted on grassland, and the adjacent grassland. The oil palm plantations were 6-25 years old.
- The sampling design accounted for spatially variable SOC content of oil palm plantations. Samples were taken to 1.5 m depth.

Analysis and Calculation Methods

All soil samples were analysed for bulk density, and then carbon content and $\delta^{13}C$, using combustion elemental analysis coupled with an isotope ratio mass spectrometer.

The fraction of SOC originating from the oil palm crop (C_{OP} {%}) for each depth increment was calculated using a formula based on that of Benoux *et al.* (1998).

$$\text{Proportion of oil palm derived SOC (\%)} = \left(\frac{\delta_{OPS} - \delta_{GLS}}{\delta_{C3S} - \delta_{GLS}}\right) \times 100$$

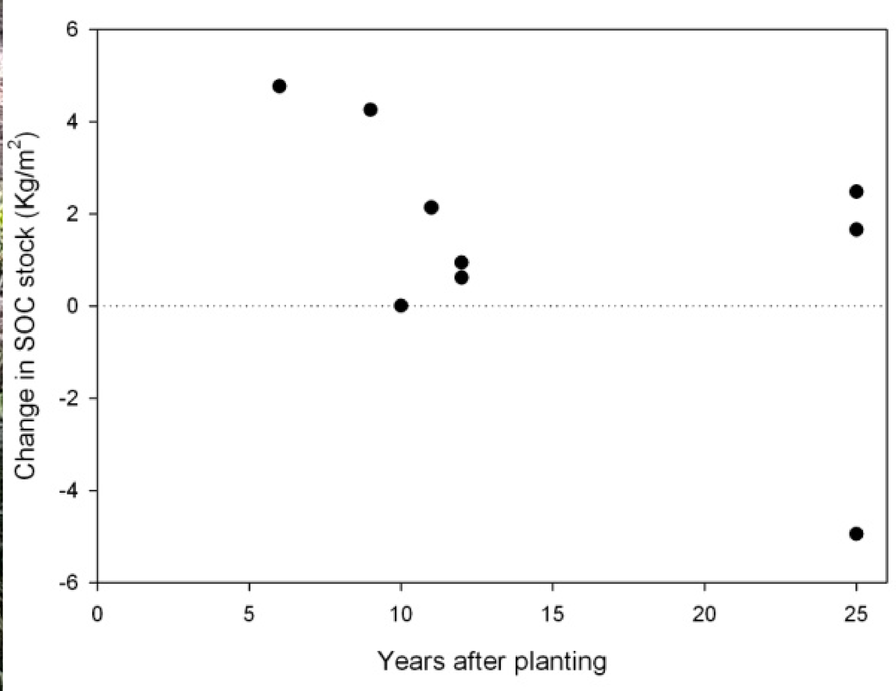
Where : δOPS = The $\delta^{13}C$ of the soil of the oil palm plantation
δGLS = The $\delta^{13}C$ of the soil of the adjacent grassland area
δC3S = The $\delta^{13}C$ of a nearby soil in which all SOC originates from C3 vegetation

Exponential functions were fitted to plots of 1) the fraction of SOC originating from the oil palm crop and original vegetation, and 2) the SOC stocks derived from oil palm inputs, against age of the oil palm plantation.

For the 0-0.05m depth interval, soil pH, electrical conductivity, nitrogen content, effective cation exchange capacity, exchangeable Al, Ca, K, Mg and Na were measured. These variables were compared to the difference between measured SOC stock derived from oil palm (% of total) and the modeled values.

Results

- SOC stocks of the grasslands were highly variable, ranging from 4.5 to 16.8 kg/m², with an mean of 10.7 kg/m².
- There was no significant relationship between change in SOC stocks and age of plantations.
- After 25 years, the proportion of SOC derived from the oil palm inputs was 28% for the 0-0.05 m depth interval and 20% for the soil profile to 1.5m.
- After 25 years, the SOC stocks derived from oil palm inputs were 0.6 kg/m² for the 0-0.05 m depth interval and 2.5 kg/m² for the profile to 1.5m.
- These values for SOC accumulation can be viewed as a turnover rate because total SOC stocks did not decrease.
- The SOC stocks in this study were more persistent than found in other agricultural systems (Trouve et al. 1994; Lememih et al. 2004).
- Deviations between modelled oil palm-derived SOC (% of total) and the actual value at each site were significantly correlated with soil nitrogen content.



Change in soil organic carbon stock following conversion of grassland to oil palm (0-1.5 m depth)

Conclusions

- SOC stocks of oil palm plantations established on grasslands were not significantly different to those of the original vegetation.
- SOC derived from oil palm inputs accumulated at 2.5 kg/m² over 25 years (0-1.5 m depth).
- Volcanic ash soils with grassland vegetation were not a CO_2 source when planted with oil palm.
- Future work will investigate reasons for the persistence of SOC stocks in this study.

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