Taking Stock of Carbon along a Land-Use Gradient in the Highlands of Java, Indonesia

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Abstract

Retaining or adding trees to cropping systems is widely assumed to increase carbon (C) stocks by building biomass, adding litter to soil, providing a stable microclimate, enhancing soil biological and physical properties and increasing temporal stability. Agroforestry may also provide landscape-level services such as watershed and biodiversity conservation and, on steep slopes in high rainfall areas, reduce the risk of soil erosion and landslides. Yet trees can compete with crops for space, nutrients and water and such trade-offs might be acute where population density is high, such as in Java Indonesia, where densities can exceed 900 km\textsuperscript{-2}.

We hypothesised that soil C stocks are higher in cropping systems where trees are included, and in abandoned tree regrowth. We selected two villages, Leksana and Penanggunan, in the Central Javan highlands (>1000 m a.s.l.). Here, maize, potatoes, vegetables and other crops are farmed on Nitisols, under a range of intensification scenarios, including or excluding trees. We compared cropped fields (i) with trees; (ii) without trees; (iii) without trees and with intensive pesticide and fertiliser use; and (iv) abandoned tree regrowth. On five fields of each type, we assessed tree vegetation (>2 cm diameter at breast height), soil C and bulk density (0–10 and 10–30 cm depths).

Trees on cropped fields were commonly two nitrogen-fixers, the native \textit{Paraserianthes falcataria}, averaging 270 stems ha\textsuperscript{-1} and the exotic \textit{Calliandra calothyrsus}, combined with both native and exotic fruit and timber trees. Mean aboveground C in trees was 6.3 Mg C ha\textsuperscript{-1}. In the abandoned regrowth, \textit{P. falcataria} densities were lower (222 ha\textsuperscript{-1}) while densities of \textit{C. calothyrsus} exceeded 11,000 stems ha\textsuperscript{-1} and aboveground C stocks were 60.4 Mg C ha\textsuperscript{-1}. Contrary to our hypothesis, soil C concentrations were high (5.1–7.9 % at

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0–10 cm depth) and neither concentrations nor stocks were significantly different between any of the plot categories, ranging from 71–89 Mg C ha$^{-1}$ to 30 cm depth. This indicates either that factors other than including trees have a stronger influence on soil C or more time is required to detect differences in such C-rich soils.

**Keywords:** Agroforestry, carbon stocks, Java, land-use gradient, space-for-time-substitution