



Improved sampling methods document decline in soil organic carbon stocks and concentrations of permanganate oxidizable carbon after transition from swidden to oil palm cultivation



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ABSTRACT

Oil palm plantations are spreading rapidly throughout Southeast Asia and in some countries, they are promoted as carbon sinks compared to the swidden cultivation systems that they often replace. However, little is known about the impacts of this land use change on soil organic carbon (SOC) stocks or soil quality. This study uses resampling of archived soil samples to investigate the sensitivity of permanganate oxidizable carbon (Pox-C) concentration to a change in land use from swidden cultivation to small-scale oil palm plantation on an Ultisol in Sarawak, Malaysia. Furthermore, the results of two different methods of calculating SOC stocks are compared – namely the fixed depth approach and the equivalent soil mass approach, which is sensitive to changes in soil bulk density. Results show that using a method that is sensitive to changes in bulk density is important as the soil bulk density increases upon establishment of oil palm. Thus, topsoil carbon stocks significantly decreased 3–8 years after oil palm establishment as measured by the equivalent soil mass approach, but only marginally and insignificantly decreased according to the fixed depth approach. After 15 years of oil palm, carbon stocks were 40% lower according to the fixed depth approach but 50% lower when using the equivalent soil mass approach. Importantly, the resampling of geo-referenced soil gives more consistent data, and lends credibility to the observation of large reductions in SOC stocks. The concentration of Pox-C in the 0–10 cm layer declines exponentially as oil palm plantations age and can serve as an indicator of change in the soil ecosystem brought about by the investigated land use transition. Pox-C is not more sensitive to this change than standard SOC analyses, but it may serve as an inexpensive, fast and field-suitable means of estimating the SOC status of different land use systems.

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1. Introduction

The last few decades have seen a rapid expansion of oil palm cultivation throughout Southeast Asia, particularly in Malaysian and Indonesian Borneo (Cramb, 2007). In the sloping uplands, oil palm plantations have mainly replaced swidden cultivation, which was once the dominant land use system in these areas. Most Asian governments have condemned swidden cultivation, as they associate the system with low productivity, deforestation, soil degradation and CO₂ emissions, despite this perception being increasingly challenged by scientists (Fox, 2000; Padoch et al., 2007; Mertz et al.,

2009; Ziegler et al., 2011). In contrast, governments all over Southeast Asia, and particularly in Sarawak, are promoting oil palm plantations. The Sarawak government target of bringing one million hectares under oil palm plantation was reached in 2010 (Cramb, 2011) and targets to reach two million hectares by 2020 have since been set (Davidson, 2012).

The transition in land use from swidden cultivation to oil palm plantations has considerable impacts on both social and natural environments, yet most research to date has focused on the socio-economic consequences (Ngidang, 2002; Hansen, 2005; Hansen and Mertz, 2006; McCarthy and Cramb, 2009), while evidence of the highly debated environmental effects of widespread oil palm cultivation remains sparse (Bruun et al., 2009; Ziegler et al., 2012). Results of the few published studies of the effects of oil palm on soil quality show somewhat conflicting results. Substantial losses of soil organic matter after conversion to oil palm have been documented by some authors (Aweto, 1995; Sommer et al., 2000), and one study reported irreversible changes to topsoil quality following

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