Changes in Soil Quality Indicators under Oil Palm Plantations Receiving Best Management Practices

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The effect of best management practices (BMPs) to intensify oil palm production and improve yield were evaluated in Indonesia and Malaysia. While no clear, consistent differences were found in the soil properties between BMP and reference (REF) treatments over four years, improvements in soil pH and % soil organic carbon (SOC) were recorded for both treatments. The study found no significant deterioration in the measured soil properties over the four years, suggesting that appropriate management practices for oil palm can improve several aspects of soil quality.

Adoption of IPNI BMPs over four years led to an extra 3.5 to 6.5 t C/ha/yr in soils under oil palm.

Indonesia and Malaysia produce 87% of the world's palm oil of 53 million t/yr, which is around 30% of the world's production of vegetable oil. Demand for vegetable oil has increased linearly since the 1970s, while demand for palm oil has grown exponentially because of its lower cost. Production has increased through area expansion, with planted area to oil palm in Kalimantan, Borneo of 903 km^2 in 1990, 8,360 km^2 in 2000, and 31,640 km^2 in 2010. This expansion was into tropical forest, both intact and logged, old rubber plantations, and peat lands. Forest accounted for 55 to 90% of the area expansion in Malaysia and Indonesia, with negative impacts on biodiversity, C accumulation, and food security.

Abbreviations and notes: N = nitrogen; P = phosphorus; C= carbon. IPNI Project # IPNI-2005-SEAP-3

Instead of increasing the area of palm oil plantations, further demand could be met by increasing current yields, which historically have grown by only 1% per yr for the past 30 years up to 2005. Better management can increase yields of palm oil from the average 4 t/ha to 5 to 6 t/ha, or as much as 8 t/ha in good years. Breeding for better yields is also feasible, but is a longer-term objective, while better management offers the possibility of better plantation performance in the short term.

Better management covers many aspects of crop and plantation operations, ranging from crop hygiene, site-specific rates and methods of fertilizer application, harvest frequency, and so on. IPNI has developed a set of BMPs best described as those agronomic practices that reduce the gap between current site yield and potential yield.

Over four years, the BMP treatment improved the harvest

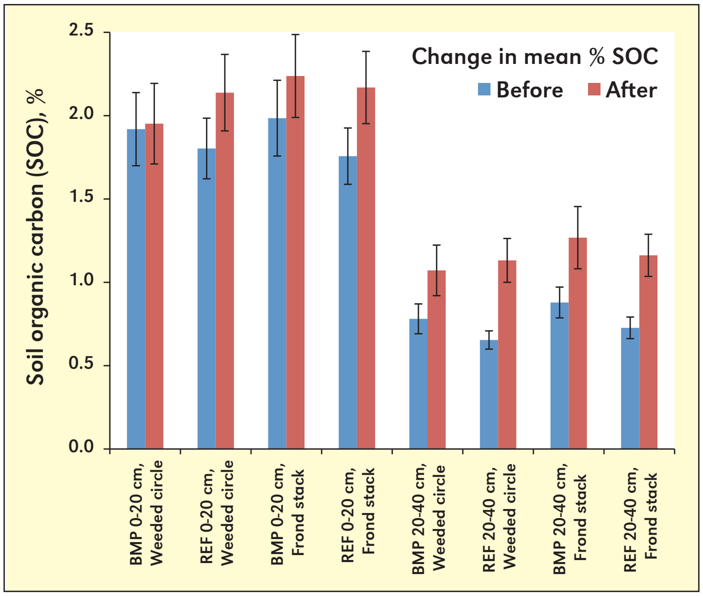

Figure 1. Change in mean soil organic carbon for each unique comparison of management, soil depth and soil sample location. n = 30 for each data point. Error bars represent the range. 'Before' refers to measurements taken at the commencement of the field trial. 'After' measurements were taken four years later at the conclusion of the trial.

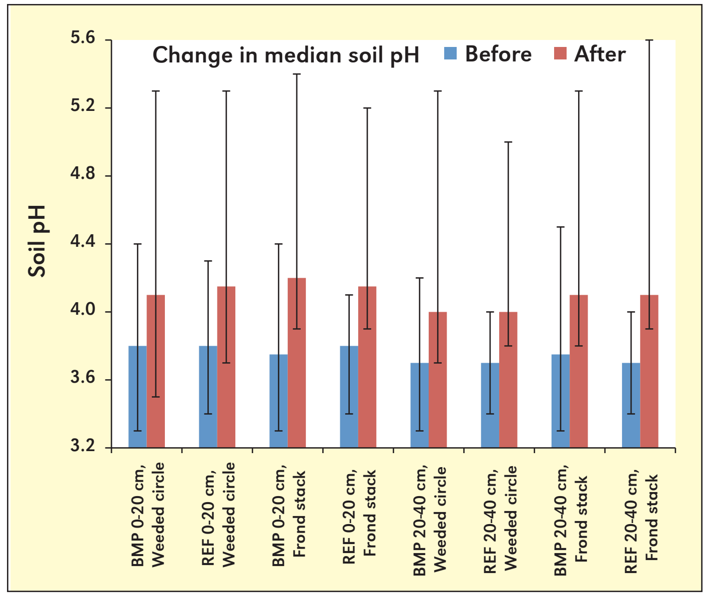

Figure 2. Change in median soil pH for each unique comparison of management, soil depth and soil sample location. n = 30 for each data point. Error bars represent standard error. 'Before' refers to measurements taken at the commencement of the field trial. 'After' measurements were taken four years later at the conclusion of the trial.

by increased crop recovery and also by increased crop productivity. Yield improvements at the six sites ranged from 1.5 to 5.4 t of fresh fruit bunches per ha (Pasuquin et al., 2014). It is not known, however, what impact BMP might have on soil properties compared with standard plantation management. The objective of the experiment was to compare the effect of BMP compared with standard management on a range of soil properties across representative sites in Indonesia.

Six sites were chosen in Indonesia on the islands of Sumatra and East Kalimantan, located over 3.5° of latitude and almost 17° of longitude. The climate for all sites was humid equatorial with rainfall varying from 1,900 to 3,100 mm. Four sites experience no water stress during the year; one has water deficits in some years, while the sixth has severe water deficits in many years. Mean annual temperatures of the six sites were similar, 26.6 to 27.1°C. Most sites were flat, with some undulating to hilly areas in places. Soil texture varied from clay to loamy sand.

A palm plantation consists of several estates (2,000 to 5,000 ha) within which the smallest management unit is a block (25 to 30 ha). We identified one commercial partner plantation at each of the six study sites. Within each selected plantation, five pairs of blocks were distributed over 1 to 5 estates. Estates within a selected plantation were no more than 30 km apart.

Each pair consisted of two adjacent blocks with similar terrain and soils, using soil surveys if they were available or on-site selection if not. The blocks within each pair were as similar as possible, sown in the same year with seed from the same source, had the same management history, especially fertilizer, and similar yields.

One block of each pair was allocated to estate management (REF), the second received IPNI's BMPs. BMP varied between sites but in general, blocks were harvested more frequently (at intervals no more than 7 to 8 days compared to 10 to 13 days). There was little difference in fertilizer applications except increased P from 80 to 180 kg/ha at site 1 in North Sumatra.

In some blocks close to the oil mills, empty fruit bunches (EFB) were applied to the inter-row area in the BMP treatment aiming for 40 t/ha/yr. BMP included removing senescent fronds and surplus fronds to achieve a leaf area index of 5 to 6. Removed fronds were stacked between the rows of palms. On some but not all blocks, BMP included additional drainage, culling unproductive and diseased palms, removing woody weeds and epiphytes, and control of insect pests.

Each block was sampled on a fixed grid, 30 to 36 points depending on the area of the block, 1 m from the trunk (within the weeded circle), and also under the stack of fronds in the inter-row space. Soils were sampled 0 to 20 cm and 20 to 40 cm at the start and end of the experiment. Samples within a block were bulked and sub-sampled (500 g) for analysis of texture, pH, SOC, total N, available P and exchangeable cations.

BMP vs. REF Blocks

Soil properties did not differ significantly between the BMP and REF blocks after the four years of the trial. This was unexpected, especially as the BMP blocks yielded more than the REF blocks. Certainly, the variability between paired blocks in commercial plantations makes it difficult to show statistical significance in a period as short as four years. Moreover, estate managers may have incorporated some of the aspects of BMP into REF management.

While soil analysis was not a useful indicator of oil palm yield, soil pH and SOC both increased in the BMP and the REF treatments during the four years of the experiment (**Figure 1 and 2**). The increase in median pH varied between 0.3 to 0.45 units in both the BMP and REF blocks and at both soil depths. The differences were greater under the frond stacks than under the weeded circle.

Differences in SOC were almost statistically significant.

The most important feature was that SOC percentage increased by about the same amount in the 20 to 40 cm depth as in the surface soil, with a range 0.03 to 0.48%. If we ignore the lowest figure, the range is 0.25 to 0.48%. At a bulk density of 1.4 g/cm^3, common in plantation soils, the increase in SOC is 14 to 26 t/ha over the four years of the experiment (to 40 cm depth), or 3.5 to almost 6.5 t C/ha/yr.

These are very high figures, but show considerable opportunity to contribute as potential sinks for atmospheric CO_2. Fisher et al. (1994, 1997) showed that an introduced African oil palm-type on the eastern plains of Colombia accumulated C as deep as 80 to 100 cm. It would be worthwhile in future work to sample the soil to at least 1 m. As might be expected, the increases were greater under the frond stacks than in the weeded circles around each palm. This contrasts with the observation of increasing soil acidification and decreased carbon stocks under oil palm plantations reported elsewhere. The question clearly requires further work.

Summary

The results show that with reasonable management, soil quality under oil palm can improve. It may be that in the longer term, BMP may be shown statistically better than standard plantation management. It would be useful to revisit these sites in 10 years' time.

There was no significant deterioration in the soil properties measured over the four years of study. However, in both management treatments soil pH and SOC increased, indicating that appropriate oil palm management techniques can help improve soil quality. Further research on the mechanisms by which BMPs can improve soil quality, and monitoring over longer periods of time is recommended to give plantation managers a clearer picture of the potential 'co-benefits' that can be obtained with adoption of BMPs designed to increase oil palm yield.

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