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Dynamics of soil carbon sequestration under oil palm plantations of different ages

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Abstract

Farming system transformations such as replacing forests with oil palm have generated some arguments owing to the perceived negative impacts of oil palm on the environment. A change in management practices such as heaping of pruned branches could increase carbon stocks. The objectives of this study were to assess soil carbon content, stocks and dynamics over time in oil palm plantations. Oil palm plantations of five different ages were chosen based on similar land history fairly located at the bottom slope. On the same farm two different samples were taken; first within alleys; and secondly under heaped pruned branches. A control was selected from a forest reserve. The carbon content determined showed that organic carbon under alleys fairly decreased with age whiles that under prunnings increased. Carbon stocks calculated followed a similar pattern. The use of carbon saturation deficit showed how much carbon each age group needed to add in order to attain equilibrium. The closest was the 20-25 years group under prunnings indicating a positive feedback compared to the rest when pruned materials were added. In conclusion oil palm plantations have the ability to sequester carbon when residue materials in the form of pruned palm fronds are well managed.

Keywords: oil palm, prunning, heaps, alley, carbon, sequester, decomposition.

Introduction

Tackling climate change demands special attention to agriculture since growing of crops and raising of farm animals contribute an estimated 10-12% of anthropogenic greenhouse gas emissions globally (Smith *et al.* 2008). Farming system transformations in the humid tropics involving the replacement of forests with cash crops have also generated a lot of controversies with respect to CO_2 emission. For example the large scale cultivation of oil palm has been implicated as one of the major causes of substantial gas emission and often irreversible damage to the natural ecosystem.

In the Eastern Region of Ghana some farmers have engaged in converting primary and secondary forests into oil palm plantations. The farmers engage in periodic prunning and the heaping of palm fronds in between the rows of plants during the growth of the crop. Information on the impact of this management practice especially on organic matter and its constituent carbon (C) in Ghana is scarce.

According to Youl (2009) a change in any management practices leading to an increase in C stocks (sink) represents a means to reduce CO_2 concentration in the atmosphere which is responsible for the increase of the earth's surface temperature (GIECC, 1997).

The objectives of this research were: (1) to assess soil C content and stocks under pruned heaps in already established oil palm plantations of different maturity ages; (2) to examine the dynamics (changes) in soil C stocks over time under pruned heaps in these oil palm plantations.

Materials and methods

Private oil palm plantations owned by local farmers within the Kwaebibirim District of the Eastern Region, Ghana, were selected with a reference soil, (uncultivated forest soil) taken from the Forest and Horticultural Crops Research Centre, Okumaning, Ghana within the same district.

These oil palm farms were at different maturity ages from very young ones of about three months old to farms as old as twenty-five years. Sampling of farms begun with creating five clusters according to

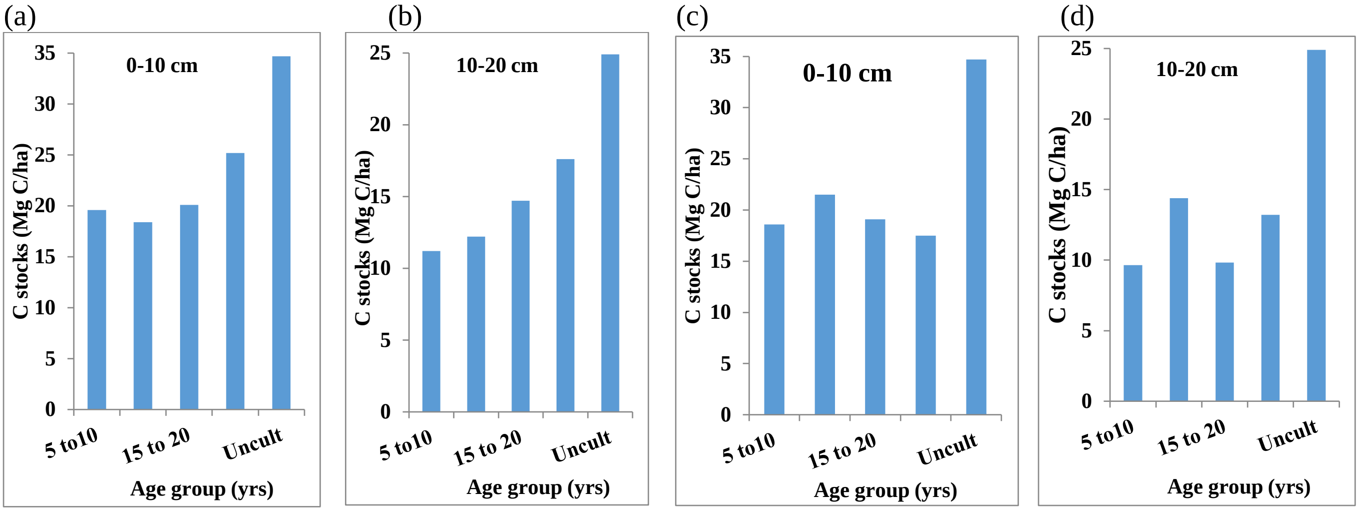
age of oil palm plantation into which various farms were grouped. A total of fifteen farms were selected for sampling with three farms representing each age group as replicates. The sites selected were oil palm farms established at the valley bottom along a typical catena. The dominant soil at this location is Oda Soil Series classified as *Aeric Endoaquent* (Owusu-Bennoah *et al.*, 2000). Soils were sampled from a depth of 0-10 and 10-20 cm. The various age groups considered were 0-5, 5-10, 10-15, 15-20 and 20-25 years. Sampling was preceded by marking out an area 25m by 25m. These sampling plots contained both alleys between rows of palm trees and pruned and heaped palm fronds within the palm rows. Core samplers were driven into the ground to take undisturbed soil samples within the alleys and under heaped branches for bulk density analysis. Sampling under the prunnings was done carefully especially under old heaps since there was the need to distinguish the top layer from the decomposed material sitting just above it. Soils from the sampled spots from each farm were put together to obtain a composite sample. A sub-sample was taken, air dried, crushed and sieved through a 2 mm sieve and processed for laboratory analyses. Bulk density, particle size analysis (Bouyoucos Hydrometer, Day (1965)), pH (Electrometric), Organic Carbon (Wet Oxidation, Walkley and Black (1934)), Total Nitrogen (Kjeldahl Digestion, Bremner (1960)), Exchangeable bases and CEC (1M Ammonium acetate solution at pH 7.0) were among the properties determined. Carbon stocks for each layer i.e. 0-10 and 10-20 cm were determined on the fine earth fraction after bulk density and C content had been determined on the soils using the formula below: C stocks ($\mathrm{Mgha^{-1}}$) = ρb $\left(\frac{\mathrm{Mg}}{\mathrm{m^3}}\right) \times \mathrm{C\ content} \left(\frac{\mathrm{kg}}{\mathrm{kg}}\right) \times \mathrm{a}\ (\mathrm{m^2}) \times \mathrm{d}\ (\mathrm{m})$, where ρb- Bulk density a- Area of a hectare, d- Sampling depth (Youl *et al.* 2011). Carbon saturation deficit was calculated from stocks for each of the layers using:
Csatdef = $\frac{(\mathrm{Cref}-\mathrm{Corg})}{\mathrm{Cref}} \times 100\%$, where Cref- Carbon stock in reference soil and Corg -Current carbon stock in sampled soil under oil palm (van Noordwijk *et al.* 1997). Genstats (12th Edition) and Minitab (16th Edition) were used for computer analyses. Separation of means was done using the Least Significant Difference (LSD) method. All tests were conducted at 5% significance level.

Results and discussion

Prunning and heaping of palm fronds by the farmers starts after the initial 5 year period of the establishment of the plantation and so marked the beginning of the dynamic study. The initial 0-5 years enabled comparison to be made between the reference and cultivated sites after clearing.

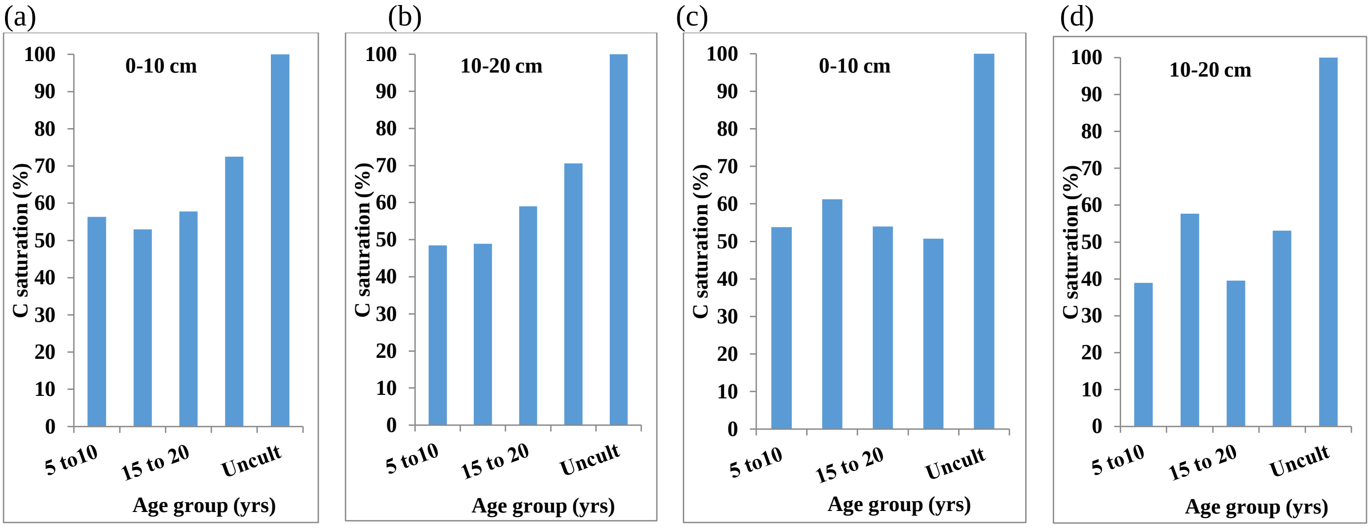
A general increase in bulk density (BD) with depth was observed under prunnings and alleys which was attributed to the increasing clay content with depth (Brahene *et al.* 2015). Opening the forest to cultivation led to loss of C into the atmosphere from both soil and vegetation. The difference between the 0-5 years and the uncultivated was significant with a substantial amount of C present on the soil surface after initial removal of vegetation. With the 0-5 years serving as a reference for the cultivated fields a notable drop in OC within the first 5 years was seen as has been reported in other studies by Guo and Gifford (2002). The subsequent drop in OC beyond 10 years was gradual when compared to preceding years as has been observed in a similar study. Although significant litter was present on the forest floor the OC determined was 40.7 g C/kg soil for the 0-20 cm which was relatively low as has been reported by Nye and Greenland (1962) for humid tropical soils. The organic carbon content under pruned palm fronds increased consistently at a rate of 6.4% from 5-10 years up to 15-20 years but was not significant. Beyond 20 years the increase observed was significant and was about 24% of the OC determined for the 15-20 years period. Organic carbon was higher in the 0-10 cm than the 10-20 cm layer for all age groups. The OC content for soils within the alleys followed a similar trend as that under prunnings except that there was a significant decline beyond 20 years.

Carbon stocks in soils from uncultivated, prunnings and alleys followed a similar trend as C content. The C stocks measured under pruned heaps for the 0-5 years was significantly higher than that for the 5-10 years. Beyond 10 years it decreased marginally at a rate of 1.22 % but increased by 8.46% for the 15-20 years and further by 20.24% to attain the 25.2 Mg C/ha observed under the 20-25 year group as shown in figure 1 below. Increases in C stocks were observed with age with a decrease beyond 20 years for both layers for soils within the alleys with the upper layer being significantly higher than the lower layer. When C stocks for both layers were summed up, it was observed that soils under prunnings had higher values than the alleys particularly for the 20-25 year group, giving a value of 59.6 Mg C/ha.



Figs. 1 Relationship between C stocks (MgC/ha soil) and Age of oil palm plantation (years) in the (a) 0-10 and (b) 10-20 cm layer under prunnings; (c) 0-10 and (d) 10-20 cm within alleys.

The Csatdef calculated increased initially up to 10 years and decreased gradually at 10.2 % until a further decrease of about 34.8% was observed for 20-25 years for the upper layer under pruned fronds. In the lower layer significant differences were observed among some age groups. The Csatdef in the 0-10 cm layer under alleys showed relatively higher values for the deficit. For the 10-20 cm layer very high values of about 61 % were noted with the trend being similar to those of the upper layer within the alleys. The results of the present study seem to suggest that the soil under the prunnings for 20-25 years would require less organic matter for the 0-10 cm layer than those within the alleys to reach the OC level of the reference. The 20.3 % obtained for the 0-5 years has shown that although the soil lost some C due to removal of vegetation, decomposition of litter and in some cases burning, good management practices could restore such a soil to its equilibrium. The amount of C saturation with age is shown in Figure 2 below.



Figs. 2 Relationship between C saturation (%) and Age of oil palm plantation (years) in the (a) 0-10 and (b) 10-20 cm layer under prunnings; (c) 0-10 and (d) 10-20 cm within alleys.

It can be seen that the presence of pruned materials influenced C stocks in the upper layer of soils under prunnings compared to the same layer under alleys with significant differences. In addition to the annual increases in stocks under prunnings, some organic materials are still present on the farm at various stages of decomposition serving as a means to trap and hold C and other gases (released via decomposition).

Conclusion and recommendation

The Carbon saturation deficit (Csatdef) proved useful and could be used for future studies. Based on the Csatdef, the higher the index the more OC is needed to sequester C.

From sequestration point of view, materials with high C:N ratios (Brahene *et al.* 2015) are good since they would persist longer in soil and so contribute to C storage. The practical implications of this research would be to encourage prunning and heaping of palm fronds within rows of palm trees at well designated spots continually; an action which would not only provide nutrients to the crops but would with time contribute to building up of C levels in the soils.

The study recommends research into how to improve decomposition of oil palm residue to enhance the fertility of the mineral soil as infiltration through the fronds becomes limiting with increasing height of heaps.

References

Brahene, S.W., Owusu-Bennoah, E. & Abekoe, M.K. (2015). Physico-chemical properties of soils under oil palm plantations of different ages. Nature and Faune 30, 54-58.

Bremner J.M., (1960). Determination of N in Soil by Kjeldahl Method. Journal of Agricultural Science, 55: 11-33.

Day P.R., (1965). Particle Fractionation and Particle Size Analysis. *In*: Black et al. (Eds) Methods of Soil Analysis, Part I, Agronomy 9: 545-567.

GIECC (1997). Protocole de Kyoto a la Convention Cadre des Nations Unies sur les Changements climatique. Uno, Kyoto, japan, p 24

Guo, L., & Gifford, R. (2002). Soil Carbon Stocks and Land Use Change: A Meta-Analysis. Global Change Biology, 8(4), 345-360.

Nye, P.H. & Greenland, D.J. (1960). The soil under shifting cultivation. Commonwealth Bureau of Soils, Technical Communication 51. Commonwealth Agriculture Bureau; Farnham Royal

Owusu-Bennoah, E., Awadzi, T.W., Boateng, E., Krog, L., Breuning-Madsen, H. & Borggaard, O.K. (2000). Soil Properties of a Toposequence in the Moist Semi Deciduous Forest Zone of Ghana.West African Journal of Applied Ecology Vol. 1, 2000.p 1-10

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H.H., Kumar, P. ..… Smith, J.U. (2008). Greenhouse Gas Mitigation in Agriculture, Philosophical Transactions of the Royal Society B, vol. 363, pp. 789-813.

van Noordwijk, M. Cerri, C. Woomer, P.L., Nugroho, K. & Bernoux, M. (1997). Soil Carbon Dynamics in the Humid Tropical Forest Zone. Geoderma 79:187-275.

Walkley A. & Black C.A., (1934). An Estimation of the Degyjareff Method of Determining Soil Organic Matter and a Proposed Modification of the Chronic Acid Titration Method. Soil Science 31: 29-38.

Youl, S., Itien, E, Manlay, R.J.,Masse, D., Hien V & Feller, C. (2011). Natural and Entropic Determinants of Soil Carbon Stocks in Two Agro-Ecosystems in Burkina Faso. *In* Bationo et al., (Eds) *Innovations as Key to the Green Revolution in Africa.* Springer Science. Pg 539-551.