The African Journal of Plant Science and Biotechnology ©2012 Global Science Books

Estimating Organic Carbon from Loss-on-Ignition and pH in some Soils of Cameroon Rubber (*Hevea brasiliensis*) Plantations

Jetro Nkengafac Njukeng[1*] • Eugene E. Ehabe[1] • George E. Nkeng[2]

[1] Institute of Agricultural Research for Development (IRAD), Ekona Regional Centre, PMB 25 Buea, South West Region, Cameroon
[2] National Advanced School of Public Works (ENSTP) Yaoundé, B.P. 510, Yaoundé, Cameroon

***Corresponding author*: * jnkengafac@yahoo.com**

ABSTRACT

Recent studies on carbon sequestration and climate change require accurate estimates of soil organic carbon (SOC) following its importance in carbon storage studies. This study evaluates the use of loss-on-ignition (LOI) as a rapid, less costly and accurate method for estimating SOC considering the errors associated with estimation of the latter. LOI-SOC-pH regression equations were obtained using data from analyses of topsoils (0-15 cm deep) in mature rubber plantations in the humid forests of south west Cameroon. Indeed, significant linear equations characterized SOC-LOI and SOC-pH (KCl) relations. The rather weak LOI-SOC relations ($r^2 \leq 0.38$) would indicate that this parameter may serve as an accurate estimate for SOC upon its modification following a mastery of factors responsible for its variability.

Keywords: linear relations, rubber plantations, soil organic carbon, soil pH
Abbreviations: LOI, loss on ignition; **SOC**, soil organic carbon; **SOM**, soil organic matter

INTRODUCTION

Soil organic carbon (SOC) seriously affects soil quality and agriculture sustainability as it not only constitutes a source and sink of plant nutrients that enhance crop production (Post and Kwon 2000), but also plays an important role in the terrestrial C cycle (Freixo *et al.* 2002) and in mitigating greenhouse gas emissions (Post and Kwon 2000). Under favorable environmental conditions, tropical soils are often characterized by high rates of decomposition of their soil organic matter. The fertility status of these weathered soils, especially those under low input agricultural systems, strongly depends on the quantity and quality of their soil organic matter - SOM (Agboola and Corey 1973). Nutrient depletion and loss of soil organic matter are therefore issues of concern to ecologists and soil resource managers (Zang *et al.* 2007).

SOC is often used in assessing land use-induced changes when evaluating agro-ecosystem transformation and sustainable land productivity (Yao *et al.* 2010), and as an indicator of soil quality and a broader indicator of ecosystem response to environmental changes. The methodology for C assessment is critical for accurate quantification of SOC concentrations and content (Périé and Ouimet 2007). Several methods are available for the analysis of soil organic carbon, each having advantages and disadvantages in terms of accuracy, cost, and convenience. Loss-on-ignition (LOI), which involves weight loss evaluation following specimen combustion at high temperatures, has been proposed as an alternative for estimating SOC (Ball 1964). Recently, research efforts have focused on measuring soil C *in situ* using a variety of spectroscopic methods (Gehl and Rice 2007), which are, nonetheless, considered rather expensive.

Soil pH affects all of a soil's properties (Brady and Weil 2002) and as such, the availability of soil nutrients and eventual crop growth and production (Bacchewar and Gajbhiye 2011). SOC equally increases with increasing total nitrogen (Wang *et al.* 2008) and soil cation exchange capacity (Rashidi and Seilsepour 2008) while the SOM decreases with increasing soil pH (Dai *et al.* 2009). Indeed, soil pH is a relatively easy parameter to measure and, where feasible, could be used for the estimation of soil organic carbon. Even soil available P has been estimated from soil organic carbon: $R^2 \approx 0.92$ (Seilsepour *et al.* 2008). In a bid to obtain a technique for the rapid determination of soil organic carbon concentrations, this study sought to derive relations between SOC values from different analytical techniques, as well as between SOC and soil pH.

MATERIALS AND METHODS

Study area

Forty four (44) composite topsoil samples were collected from 11 rubber estates belonging to the Cameroon Development Corporation of Cameroon – **Fig. 1** (4° 14′ - 5° 20′ N lat. and 8° 30′ - 10° 12′ E long.). The choice of the number of samples was conditioned by the field size, clones to which they were planted and the age of the plantation.

Soil sampling and analysis

Sample collection involved removal of surface organic debris and augering to a depth of 0-15 cm. Each sample consisted of at least 10 sub-samples from the entire sampled area. On arrival at the laboratory, samples were air-dried and passed through 2-mm sieves in preparedness for eventual analyses.

Soil pH was measured using a pH meter (Ingold Electrode 405.88 S7, Paris), in water (pH-H_2O) and in potassium chloride (pH-KCl). For each analysis, 10 g of soil were poured in separate 25-mL solutions (distilled water and 1M KCl), stirred with a glass rod, left overnight, and the pH read using calibrated electrodes.

Two techniques were used to determine soil organic matter and organic carbon contents. The first involved use of the Walkey and Black (WB) procedure (Walkey and Black 1934) while the second involved determination of organic carbon using the LOI method. The LOI method involves oven-drying at 105°C for 2 h,

Received: 30 December, 2011. Accepted: 12 March, 2012.

Short Communication

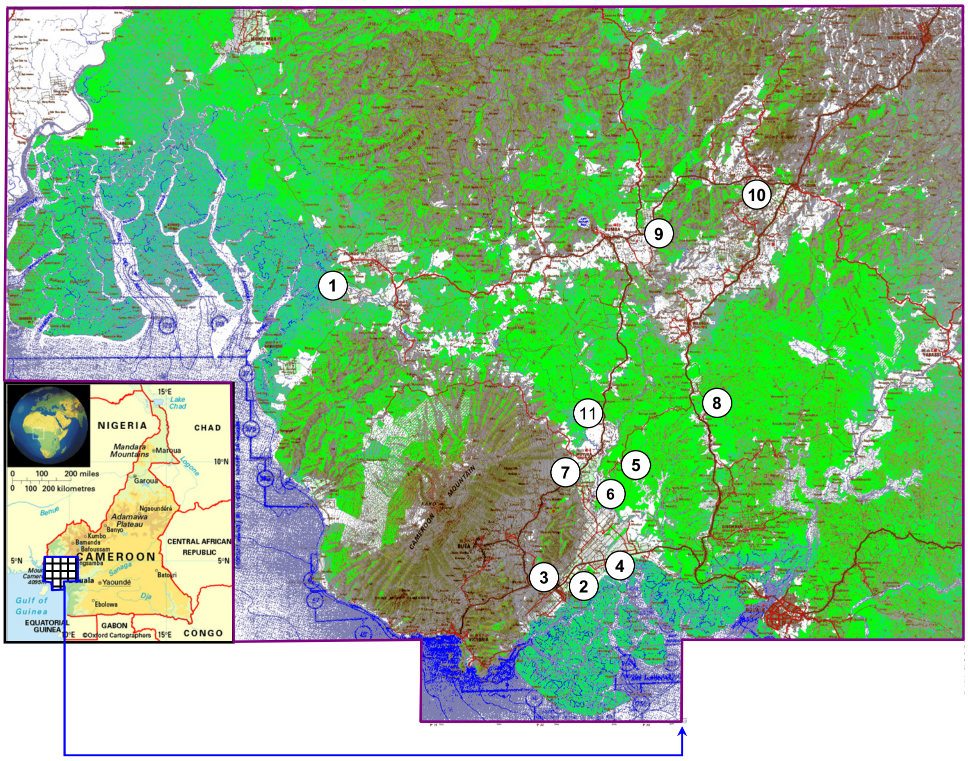

Fig. 1 Location of rubber estates where soil samples were collected. 1 = Mbonge, 2 = Sonne, 3 = Likomba, 4 = Missellele, 5 = Penda Mboko, 6 = Matouke, 7 = Meanja, 8 = Kompina, 9 = Mukonje, 10 = Tombel, and 11 = Malende.

cooling in a desiccator to room temperature, weighing, charring at 550°C in a muffle furnace (model Carbolite 1100) for 4 h, further cooling in a desiccator and weighing. The SOM was calculated as the difference in mass of each specimen after oven-drying and after ashing, and the organic carbon content obtained by dividing organic matter content by a factor of 1.72.

All analyses were conducted in duplicate.

Statistical analysis

Regression analyses were used to describe relationships between all measured variables using the JMP Statistical Discovery Software ver. 5.0 (SAS Institute Inc., 2002). The Student *t*-test at 1% and 5% levels were applied for simple correlations.

RESULTS AND DISCUSSION

Mean pH and organic carbon values for all the plots studied are presented in **Table 1**. Soils of the studied area were acidic with pH (H_20) of 4.3 to 6.5 and pH (KCl) values of 4.1 to 6.7. The percentage organic carbon values obtained using the LOI and WB methods ranged from 3.1 to 15.3 and from 0.1 to 5.9, respectively.

Simple correlations between variables were performed and the Student's *t*-test was separately applied at 5% and 1% probabilities. The mean results are presented in **Table 2** while equations representing relationships are presented in **Table 3**.

The WB organic carbon showed significant correlations with pH (KCl) and organic carbon obtained using the LOI technique. However, no significant relationships were observed between SOC obtained using the WB method and pH (H_2O).

Bivariate fits of WB SOC by the other variables gave more significant linear fits with pH (KCl) and LOI organic carbon. Such fits were not significant with pH (H_2O) and LOI organic carbon (**Table 3**). In most of the relations, the R^2 values were generally low, less than 0.38 (**Fig. 2**).

Linear equations described relations between SOC and LOI better than other models. Though of lower magnitudes, these results compare favourably with those obtained elsewhere by Christensen and Malmros (1982). Reasons for these differences are unclear but any efforts to reduce errors involved in the LOI and SOC determinations would certainly improve on these relations.

Indeed, R^2 values have been reported not often optimal for estimating and assessing relations that are not truly linear (Neter *et al*. 1996; Harris *et al*. 2001) although most research efforts, like in this study, are meant to develop simple, readily useable equations (Konen *et al*. 2002). Yerokun *et al*. (2007) working on WB-OC and LOI relationships of Zambian soils obtained significant linear correlations, the constants of which were different from that obtained in this study, though. The weak LOI-SOC relationships obtained here could be attributed to the inconsistencies in the methodology in measuring both SOC and LOI, such as the fairly

Table 1 Average pH and organic carbon for the 44 samples collected.

Variable	**Average value**
pH H_2O	5.27
pH KCl	4.75
% OC (Walkey-Black method)	1.43
% OC (LOI method)	6.25

Table 2 Table of correlation between parameters.

Correlation	**Correlation coefficient (r)**	**Significance**
WBOC x pH H_2O	0.1886	ns
WBOC x pH KCL	0.4216	**
WBOC x LOI	0.4022	**
pH H_2O x pH KCL	0.6204	**
pH H_2O x LOI	0.0721	ns
pH KCL x LOI	0.1413	ns

** Significant at a level of 1% of probability ($P < 0.01$); ns Non-significant ($P \geq 0.05$)

Table 3 Equations relating variables and significance probability (Prop>|t|

Equation	**Prop > |t|**
WBOC = 0.075542 + 0.2570838 pH H_2O	0.2203 ns
WBOC = -1.599717 + 0.6385372 pH KCl	0.0044 **
WBOC = 0.7414283 + 0.1101725 LOI	0.0068 **
pH H2O = 1.9992696 + 0.6892823 pH KCl	0.0001 **

ns = not significant; ** = Significant at 1% alpha level

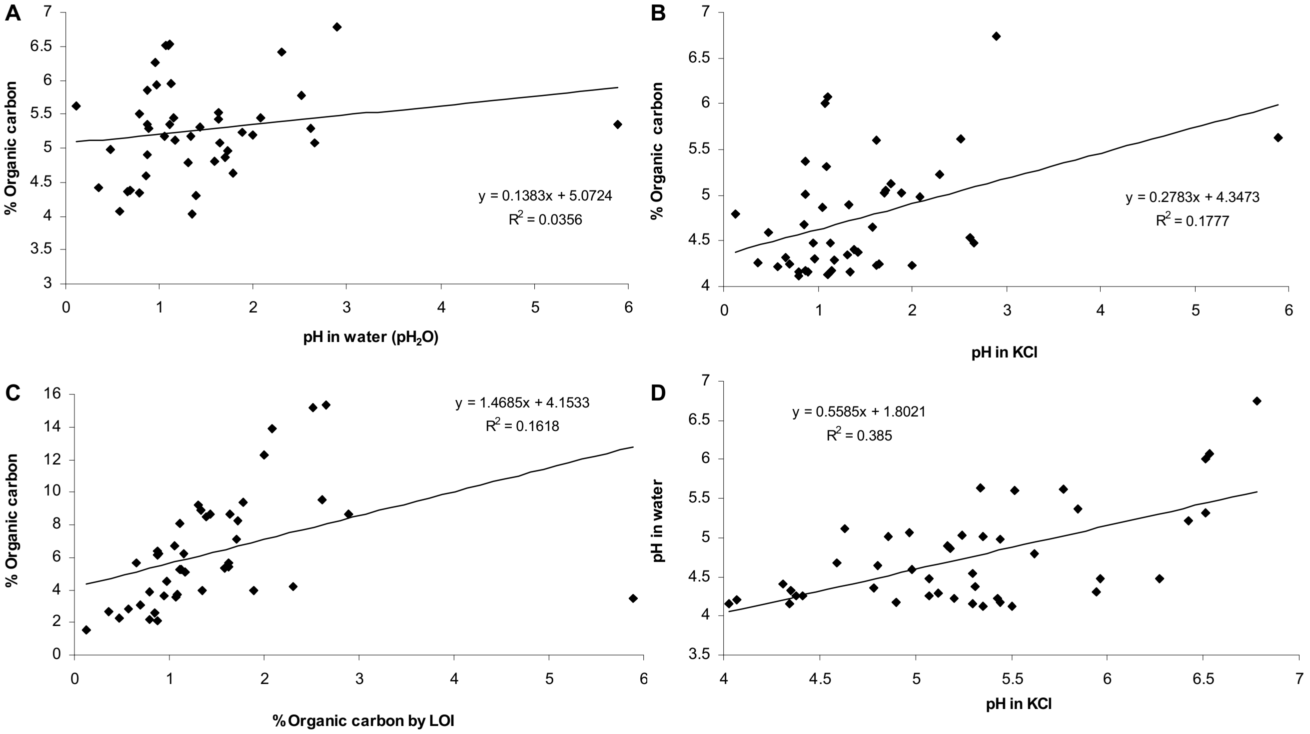

Fig. 2 Equations relating to variables measured in soil. (**A**) SOC vs. pH in water; (**B**) SOC vs. pH in KCl; (**C**) SOC vs. LOI; (**D**) pH in water vs pH in KCl. In all cases, SOC measured by the Walkey-Black method.

narrow range of SOC values obtained (though inherent to the soils studied). Where these ranges have been quite large, the R^2 values characterizing the linear relations have been acceptably high (Christensen and Malmros 1982), indicating therefore the need for the derivation of WB-OC and LOI models that are specific to each soil type and geographic region.

SOM is directly related to SOC. Positive linear relations acceptably described relations between SOC and pH (KCl) by as much as 18% of the variation in SOC although negative correlations have been obtained elsewhere, in China (Dai *et al.* 2009).

ACKNOWLEDGEMENTS

The authors are grateful to the managements of the Institute of Agricultural Research for Development (IRAD), Cameroon and the Cameroon Development Corporation (CDC) for financial and other logistic support for this study.

REFERENCES

Agboola AA, Corey RB (1973) The relationship between soil pH, organic matter, available phosphorus, exchangeable calcium, magnesium and nine elements in maize tissue. *Soil Science* **115**, 367-375

Bacchewar GK, Gajbhiye BR (2011) Correlation studies on secondary nutrients and soil properties in soils of Latur District of Maharashtra. *Research Journal of Agricultural Science* **2**, 91-94

Ball DF (1964) Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. *Journal of Soil Science* **15**, 84-92

Brady NC, Weil RR (2002) *The Nature and Properties of Soil* (13th Edn), Springer, Netherlands, 249 pp

Christensen BT, Malmros PA (1982) Loss-on-ignition and carbon content in a beech forest soil profile. *Holarctic Ecology* **5**, 376-380

Dai WH, Yao H, Li W, Jia Y (2009) Relationships between soil organic matter content (SOM) and pH in topsoil of zonal soils in China. *Acta Pedologica Sinica* **46**, 851-860

Freixo AA, Machado PL, Santos HP, Silva CA, Fadigas FS (2002) Soil organic carbon and fractions of a Rhodic Ferralsol under the influence of tillage and crop rotation systems in southern Brazil. *Soil Tillage Research* **64**, 221-230

Gehl RJ, Rice CW (2007) Emerging technologies for *in situ* measurement of soil carbon *Climatic Change* **80**, 43-54

Harris IR, Burch BD, St. Laurent RT (2001) A blended estimator for a measure of agreement with a gold standard. *Journal of Agricultural, Biological and Environmental Statistics* **6**, 326-339

Konen ME, Jacobs PM, Burras CL, Talaga BJ, Mason JA (2002) Equations for predicting soil organic carbon using loss-on-ignition for north central U.S. soils. *Soil Science Society of America Journal* **661**, 878-881

Neter J, Kutner MH, Nachtsheim CJ, Wasserman W (1996) *Applied Linear Statistical Models*, Irwin Publ., Chicago, IL

Post WM, Kwon KC (2000) Soil carbon sequestration and land-use change: Processes and potential. *Global Change Biology* **6**, 317-327

Périé C, Ouimet R (2007) Organic carbon, organic matter and bulk density relationships in boreal forest soils. *Canadian Journal of Soil Science* **88**, 315-325

Rashidi M, Seilsepour M (2008) Modeling of soil cation exchange capacity based on soil organic carbon. *Journal of Agricultural and Biological Sciences* **3**, 41-45

SAS Institute Inc. (2002) JMP® Statistical discovery software (Ver. 5.0). SAS Campus Drive, Cary, NC, USA

Seilsepour M, Rashidi M, Khabbaz BG (2008) Prediction of soil available phosphorus based on soil organic carbon. *American-Eurasian Journal of Agricultural and Environmental Science* **4**, 189-193

Walkley A, Black IA (1934) An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-37

Wang ZM, Zhang B, Song KS, Liu DW, Li F, Guo ZX, Zhang SM (2008) Soil organic carbon under different landscape attributes in croplands of Northeast China. *Plant Soil and Environment* **54**, 420-427

Yao KM, Angui PKT, Konaté S, Tondoh JE, Tano Y, Abbadie L, Benest D (2010) Effects of land use types on soil organic carbon and nitrogen dynamics in mid-west Côte d'Ivoire. *European Journal of Scientific Research* **40**, 211-222

Yerokun OA, Chikuta S, Mambwe D (2007) An evaluation of spectroscopic and loss on ignition methods for estimating soil organic carbon in Zambian soils. *International Journal of Agricultural Research* **2**, 965-970

Zang M, Fu X, Feng W, Zou X (2007) Soil organic carbon in pure rubber and tea-rubber plantations in South-western China. *Tropical Ecology* **48**, 201-207