Original

The App SOC plus a tool to estimate and calculate organic carbon in the soil profile

Francisco Bautista [a,b,*], Eduardo García [c,1], Ángeles Gallegos [c,1]

[a] *Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México, Antigua carretera a Patzcuaro SN, Morelia, Michoacán, Mexico*
[b] *Centro de Biología y Edafología Aplicada del Segura, CSIC, Murcia, Spain*
[c] *Skiu, Scientific Knowledge In Use, Mexico[1]*

Abstract

In the world, researchers are working very intensively in the development of soil organic carbon (SOC) inventories. Soil organic carbon is very important because it constitutes the largest reservoir of carbon in terrestrial ecosystems. Maintaining and increasing soil carbon is an option to reduce the amounts of CO_2 in the atmosphere, and thereby, to reduce or mitigate climate change. The SOC is now a topic of great interest hence it is recommended to know the amount of SOC along the profile to select and evaluate those areas that should be preserved. The aims of developing App SOC plus were to eliminate the calculate errors of SOC and to make a tool to estimate SOC in field. The common units of measurement of soil properties were employed: bulk density in $mg\,mL^{-1}$, horizon thickness in centimetres, stoniness and organic carbon in percentage. The App SOC plus was developed in the Android platform. App SOC plus involves a three-step process: introduction of soil properties, calculation of SOC to horizon and soil profile, and conversion of units using the international and English systems. As a result, there will no longer be confusions with conversion units using App SOC plus; with App SOC plus the soil organic carbon can now be calculated or/and estimated because it provides instructions (aids) to estimate the soil properties necessary to calculate the SOC in the soil profile. You can save time in the calculation of SOC. App SOC plus is a tool for diagnosis in the field.

1. Introduction

Intensive work is developed at a global, national and local level to elaborate the inventories of soil carbon because of its relation to the global climate change. Soil carbon is considered the largest carbon reservoir of the terrestrial ecosystems (Alvarez-Arteaga, Krasilnikov, & García-Calderón, 2012.) At a local level, areas of interest for the conservation may appear, such as the natural protected areas, the national parks and the biosphere reserves. These areas are valued because of the environmental services they offer to the society. The payment for these environmental services, among which the fixation of organic carbon stands out, is planned in some of these places the soil organic carbon calculation (Pérez, Ramírez, Bautista, & Jaramillo, 2013).

The study of soil organic carbon is now a subject of great interest, which is why it is recommendable to know the amount of soil organic carbon throughout the soil profile to select and value the areas that must be preserved.

Normally, miscalculations are shown in scientific meetings because of the unfortunate selection of the properties of the soil that is being measured, the way of expressing them with inappropriate units and because of miscalculations. Besides, the number of professionals who are not edaphologists interested in the measurement of SOC grows day by day.

The reasons to create App SOC plus are as follows: (a) normally, miscalculations are shown in scientific meetings because of the unfortunate selection of the properties of the soil that is

* Corresponding author.
   E-mail address: leptosol@ciga.unam.mx (F. Bautista).
[1] www.actswithscience.com.
   Peer Review under the responsibility of Universidad Nacional Autónoma de México.

being measured, the way of expressing them with inappropriate units and because of miscalculations; (b) the number of professionals who are not edaphologists interested in the measurement of SOC grows day by day; (c) the need to perform rapid field estimations.

The aims behind the creation of App SOC plus are (a) to decrease the miscalculations caused by the unfortunate selection of the properties of the soil, the application of the wrong equation and the inappropriate units, in which the results are expressed; (b) to offer the professionals who are not edaphologists a tool to measure the SOC; (c) to perform rapid field estimations.

2. Materials and methods

2.1. App design and development platform

App SOC plus is an application designed for the estimation of soil organic carbon from its edaphic properties. This app is compatible with all mobile devices with an Android V 4.0 or the latest operating system. In order to create App SOC plus we used: (a) SDK, the software developer tool for Android and (b) IDE Eclipse as an integrated development environment. Both are open access tools. Interfaces were designed to allow compatibility with resolution in smartphones and tablets of 7′ and 10′ (Canós, Letelier, & Penadés, 2003).

2.2. Soil organic carbon calculation

In order to calculate the soil organic carbon (SOC) the following formula is applied:

$$\text{SOC} = \sum_{i=n}^{i=1} \left(\left[\left(BD_i * (TH_i * 0.01) * \left[1 - \frac{CR_i}{100} \right] \right) * C_i \right] * 100 \right)$$

where SOC [Mg ha^{-1}]: organic carbon full profile; n: total number of horizons full profile; BD_i [g mL^{-1}]: bulk density of the horizon i; TH_i [cm]: thickness of the horizon i in cm; CR_i [vol.%]: volume of coarse fragments by horizon i; C_i [%]: percentage of organic carbon horizon i.

App SOC plus includes a simplified formula, in which the soil properties are shown in the common units in use.

App SOC plus makes it possible to calculate the organic carbon in an easy and rapid way. It is also possible to carry out estimations of the quantity of organic carbon by using the soil profile description on the field (it includes options for the estimation of the bulk density, stoniness and organic carbon on the field).

2.3. Bulk density estimation

The bulk density is measured with a cylinder of a known volume which is inserted in each horizon, then it is dried and weighed right after (Jahn, Blume, Asio, Spaargaren, & Schad, 2006; Siebe & Jahn, 1996). When the horizon has a reduced thickness or it is too compact to insert the cylinder properly, it is possible to measure the soil density by means of the aggregate density by using the clod method (Gandoy, 1992; NOM,
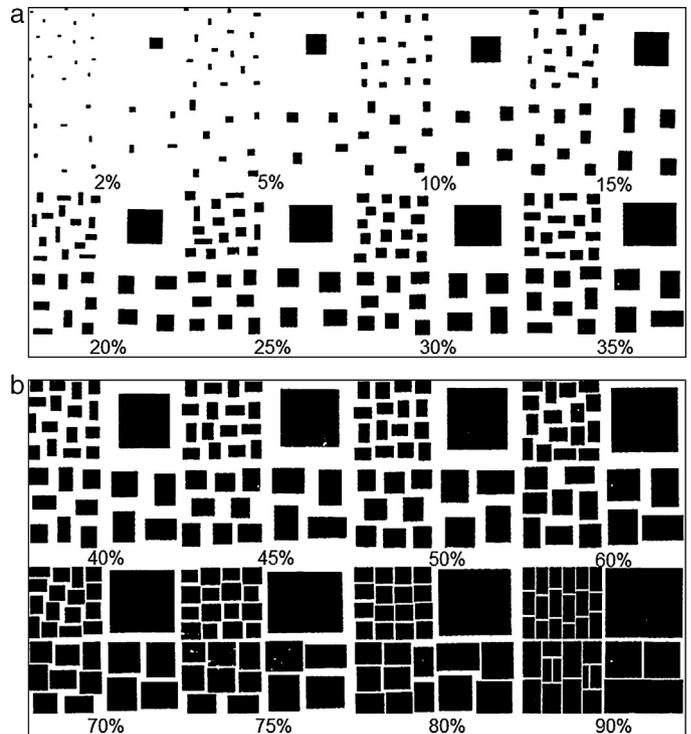

Fig. 1. (a) Images to estimate stoniness percentage in volume. (b) Images to estimate percentage in volume stoniness.

2003.) In non-aggregated soils, it is recommended to use the core method (Gandoy, 1992).

In stony soils, such as the ones on the Yucatan Peninsula, which have high carbon content in fine earth but, at the same time, have scarce fine earth, it is necessary to measure the bulk density by digging a hole in the soil and collecting fine earth, thick fragments, and afterwards, measuring the volume by lining a plastic and by filling it with water, or by using the core method.

The key from Table 1 is used in order to make the bulk density estimation on the field.

2.4. Horizon thickness measurement

A measuring tape is used in order to obtain a horizon thickness measurement. The difficulty in the process appears when the boundary between the horizons is wavy, irregular or broken. In these cases, the average depth between the horizons must be registered.

The thickness is measured in centimetres.

2.5. Stoniness or thick fragments volume

The estimation of the stone fragments volume, also called stoniness, can be carried out by comparison to Fig. 1 (USDA, 2012). The estimation of this parameter is carried out horizon by horizon. It is recommended to work with a known surface (e.g. 100 cm^2) using a cord that would be adaptable to the different horizon thicknesses.

Table 1
Guidelines to estimate bulk density (FAO, 2006).

Observation	Frequent ped shape	Bulk density (g mL^{-1})
Sandy, silty and loamy soils with low clay content.		
Many pores, moist materials drop easily out of the auger; materials with andic properties.	Granular	<0.9
Sample disintegrates at the instant of sampling, many pores visible on the pit wall.	Single grain or granular	0.9–1.2
Sample disintegrates into numerous fragments after application of weak pressure.	Single grain, subangular or angular blocky	1.2–1.4
Knife can be pushed into the moist soil with weak pressure, sample disintegrates into few fragments, which may be further divided.	Subangular and angular blocky, prismatic or platy	1.4–1.6
Knife penetrates only 1–2 cm into the moist soil, some effort required, sample disintegrates into few fragments, which cannot be subdivided further.	Prismatic, platy or angular blocky	1.6–1.8
Very large pressure necessary to force knife into the soil, no further disintegration of sample.	Prismatic	>1.8
Loamy soils with high clay content, clayey soils.		
When dropped, sample disintegrates into numerous fragments, further disintegration of subfragments after application of weak pressure.	Angular blocky	1.0–1.2
When dropped, sample disintegrates into few fragments, further disintegration of subfragments after application of mild pressure.	Angular blocky, prismatic, platy or columnar	1.2–1.4
Sample remains mostly intact when dropped, further disintegration possible after application of large pressure.	Coherent, prismatic, platy, columnar, angular blocky or wedge–shaped	1.4–1.6
Sample remains intact when dropped, no further disintegration after application of very large pressure.	Coherent, prismatic, columnar or wedge-shaped	>1.6

Note: If organic matter content is >2%, bulk density has to be reduced by 0.03 kg dm^{-3} for each 1% increment in organic matter content.

2.6. Soil organic carbon

In order to measure the soil organic carbon in fine earth (sieved through a 2 mm mesh) various methods are suitable. The common method is the wet oxidation method in an acid potassium dichromate solution; the reaction mixture temperature rises and 70% of the soil organic carbon is recovered (Nelson & Sommers, 1982).

The method of wet oxidation with potassium dichromate may be more efficient if external heat is applied to the reaction, since 100% of organic carbon will oxidize (Nelson & Sommers, 1982).

The most recommended method is the use of an auto-analysis equipment for total organic carbon; with this equipment, an oxidation by combustion is performed, the gases filter up and the CO_2 is measured. 100% of the soil organic carbon is recovered with the use of this method. There are other methods to quantify the soil organic carbon by means of UV and infrared; nevertheless, they are not frequently used. In soils with inorganic carbon, its elimination must be taken into account. It will be carried out with some acid that will not interfere with the analysis method applied later.

The organic soil can be estimated on the field by using the guide in Table 2.

Table 2
Guidelines to estimate soil organic carbon (FAO, 2006).

Colour	Munsell value	Moist soil			Dry soil		
		S	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C	S	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C
				(%)			
Light grey	7				<0.3	<0.5	<0.6
Light grey	6.5				0.3–0.6	0.5–0.8	0.6–1.2
Grey	6				0.6–1	0.8–1.2	1.2–2
Grey	5.5			<0.3	1–1.5	1.2–2	2–3
Grey	5	<0.3	<0.4	0.3–0.6	1.5–2	2–4	3–4
Dark grey	4.5	0.3–0.6	0.4–0.6	0.6–0.9	2–3	4–6	4–6
Dark grey	4	0.6–0.9	0.6–1	0.9–1.5	3–5	6–9	6–9
Black grey	3.5	0.9–1.5	1–2	1.5–3	5–8	9–15	9–15
Black grey	3	1.5–3	2–4	3–5	8–12	>15	>15
Black	2.5	3–6	>4	>5	>12		
Black	2	>6					

Adapted from Schlichting, Blume and Stahr (1995).
Note: If chroma is 3.5–6, add 0.5 to value; if chroma is >6, add 1.0 to value. S: sand; LS: loamy sand; SL: sandy loam; L: loam; SiL: silt loam; Si: silt; SiCL: silt clay loam; CL: clay loam; SCL: sandy clay loam; SC: sandy clay; SiC: silt clay; C: clay.

3. Results and discussion

3.1. App functions

In App SOC plus, click first the App logo (new estimation) and insert the horizon key; subsequently, introduce the bulk density in $g\,mL^{-1}$, the horizon thickness in cm, the stone volume or thick fragments in percentage (0–100), and finally, the soil organic carbon in fine earth (sieved through a 2 mm mesh) expressed in percentage (Table 3). Afterwards, click "calculate horizon" which will be calculated in SOC and expressed in $Mg\,C\,ha^{-1}$. Later, introduce the horizon data (Fig. 2). The total organic carbon in the soil profile appears at the bottom of the screen. Once the total SOC calculations are completed, it is possible to transform the units if necessary (Fig. 2).

Table 3

Functions of the two versions of the App SOC.

| Characteristics	SOC BETA	SOC +
Simplifying the equation for calculating soil organic carbon	X	X
Unit conversion using the international system and the English system	X	X
Aid for estimating bulk density		X
Aid for estimating stoniness		X
Aid for estimating organic carbon		X
Graph organic carbon in the soil profile		X
Graph organic carbon in the soil profile compared to other soil groups according to the WRB		X
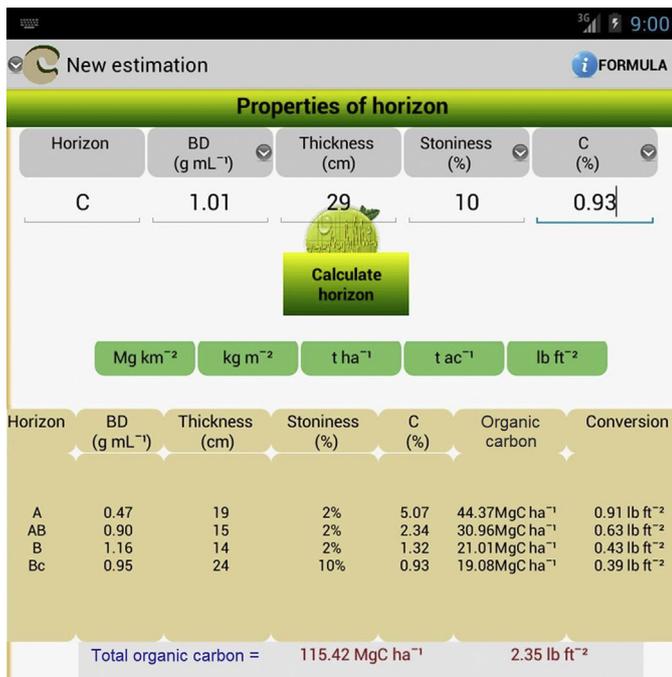
Fig. 2. Example of use of SOC App.
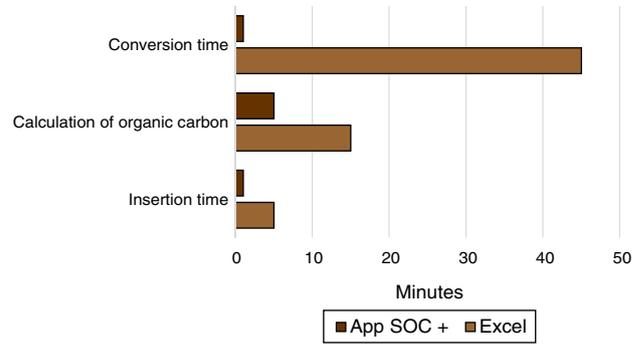
Fig. 3. Calculate time of soil organic carbon using the App SOC and excel.

It is possible to estimate the content of the soil organic carbon by using the functions to estimate the bulk density and organic carbon with tables. Besides, it is possible to obtain graphs from the carbon content throughout the profile and compare them with the organic carbon content of some soil groups provided by the WRB (Robert, 2002).

There is no similar tool to compare the efficiency of App SOC plus with.

3.2. Quick calculation

App SOC plus performs an accurate calculation and shows a rapid performance of all its functions. By comparison, an experienced technician needs 70 min to calculate one profile of five horizons with Excel; however, with App SOC plus the calculations are quickly finished in only 7 min (Fig. 3). Since work time on the field is expensive, this difference in minutes is very valuable. The app is designed to behave as a field tool, with which calculations and estimations can be done quickly and reliably.

4. Conclusions

We have now a tool with the possibility to be used on the field which allows the fulfilment of a rapid diagnosis of the content of organic carbon in the soil profile with common measure units applied on the field; it eliminates possible mistakes when calculating or applying formulas and performs rapidly.

Knowledge of the content of organic carbon in the soil profile is of primary importance to link the soil usage with its environmental functions within the ecosystem or landscape and with other ecosystems and nearby landscapes.

Conflict of interest

The authors have no conflicts of interest to declare.

Acknowledgments

References

Alvarez-Arteaga, G., Krasilnikov, P., & García-Calderón, N. E. (2012). Vertical distribution and soil organic matter composition in a montane cloud forest, Oaxaca, Mexico. *European Journal of Forest Research*, *131*(6), 1643–1651.

Canós, J. H., Letelier, P., & Penadés, M. C. (2003). *Metodologías ágiles en el desarrollo de software. Universidad Politécnica de Valencia, Valencia*. pp. 1–8. Alicante, España: Grupo ISSI.

Robert, M. (2002). *. Captura de carbono en los suelos para un mejor manejo de la tierra* (Vol. 96) Food & Agriculture Org.

Jahn, R., Blume, H. P., Asio, V. B., Spaargaren, O., & Schad, P. (2006). *Guidelines for soil description*. pp. 97. FAO.

Gandoy, B. W. (1992). *Manual de laboratorio para el manejo físico de suelos*. Chapingo, México: Universidad Autónoma Chapingo. Departamento de Suelos.

Nelson, D. W., & Sommers, L. E. (1982). Total carbon, organic carbon and organic matter. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of soil analysis. Part 2. Chemical and microbiological properties* (pp. 535–577). Madison, WI: American Society of Agronomy and Soil Science Society of America.

NOM (Norma oficial mexicana). (2003). *Diario oficial de la federación*. pp. 73. NOM-023-SEMARNAT-2001

Pérez, S., Ramírez, I., Bautista, F., & Jaramillo, P. (2013). Effects of forest management regimes on soil organic carbon content: Central mountains of Mexico. *Revista Chapingo Serie Ciencias Forestales y del Ambiente*, *19*, 157–173.

Siebe, C., & Jahn, R. S. (1996). *Manual para la descripción y evaluación ecológica de suelos en el campo* (4a. Ed.). Estado de México, México: Sociedad Mexicana de la Ciencia del Suelo, A.C.

U.S. Department of Agriculture (USDA). (2012). *Field book for description and sampling soils, version 3.0*. Lincoln, Nebraska: Natural Resources Conservation Service, National Soil Survey Center.