Soil & Tillage Research 156 (2016) 185–193

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

High resolution characterization of the soil organic carbon depth profile in a soil landscape affected by erosion

Emilien Aldana Jague[a,*], Michael Sommer[b], Nicolas P.A. Saby[c], Jean-Thomas Cornelis[d], Bas Van Wesemael[a], Kristof Van Oost[a,e]

[a] TECLIM, George Lemaitre Center for Earth and Climate, Earth and Life Institute, Université Catholique de Louvain, Louvain-La-Neuve, Belgium
[b] Leibniz Centre for Agricultural Landscape Research (ZALF) e.V., Institute of Soil Landscape Research, Eberswalder Straße 84, 15374 Müncheberg, Germany
[c] INFOSOL, INRA, Orléans 45000, France
[d] Earth and Life Institute—Environmental Sciences, Universite catholique de Louvain, Croix du Sud 2/10, 1348 Louvain-la-Neuve, Belgium
[e] Fonds de la recherche Scientifique, FNRS Rue d'Egmont 5, 1000 Brussels, Belgium

ARTICLE INFO

Article history:
Received 2 March 2015
Received in revised form 27 May 2015
Accepted 28 May 2015
Available online 27 June 2015

Keywords:
Soil organic carbon
Vertical distribution
Soil redistribution
DEM
Caesium-137
Depth function

ABSTRACT

The identification of soil management strategies as well as the evaluation of their effectiveness requires detailed information on the spatial and temporal patterns of soil organic carbon storage. High-resolution SOC profile data are generally not available and traditional methods for collecting these are time consuming and costly. Recent studies use geo-statistical approaches to assess the three-dimensional patterns of SOC storage. However, there is still a large discrepancy between the continuous and high resolution mapping of the horizontal SOC variability on the one hand, and the coarse and discontinuous mapping of the vertical SOC profile on the other. In this study, we combine spectroscopic techniques with spatial modeling in a small, cultivated catchment in Germany and we evaluate the contribution of soil redistribution processes and topographical parameters to the observed spatial and vertical patterns. Using high-resolution data from soil cores, we evaluated the robustness of a third order polynomial function to model the vertical SOC profile. Using a crossvalidation, our results show that this approach results in a robust model (RSME = 0.24%) and performs better than the widely used exponential depth model (RMSE = 0.39%). In a next step, we evaluated the relationship between the parameters of the SOC depth model and co-variables including soil redistribution (inferred from ^{137}Cs data) and topographical indices using a multiple linear regression model. The performance was calculated by cross-validation and we found a low robustness of the models because of the low number of profiles (i.e. $n = 19$). A statistical evaluation of the co-variables highlighted two key factors influencing the SOC vertical distribution. Soil redistribution processes mainly influenced the surface SOC content (first centimeters) whereas the shape of the depth distribution was controlled by slope curvature alone. The mapping of polynomial parameters was validated using an external SOC profile dataset and showed a poor prediction of the surface content but a good prediction of the depth distribution once the surface SOC content is known (RMSE = 0.15–0.25%C). This suggests that estimating the vertical SOC profile from topsoil data by applying remote sensing data, in combination with our SOC profile model, is promising and can will result in an accurate mapping of 3D SOC patterns at a very high resolution.

1. Introduction

Recently soil security has been recognized as a global challenge because soils are closely related to food and water security (McBratney et al., 2014). Soil organic carbon (SOC) is considered as a key property as it plays a central role in several environmental issues such as climate regulation, food and water security. The balance between soil carbon sequestration and C mineralization is related to soil fertility as it controls the water holding capacity and nutrient availability of soils for plant growth. Furthermore, the long-term storage of SOC in soils is also directly linked to atmospheric CO_2 concentrations as soils are the largest reservoir of terrestrial carbon (Amundson 2001). Both from a soil quality and climate mitigation perspective, carbon sequestration in soils can

* Corresponding author. Université Catholique de Louvain, TECLIM, George Centre for Earth and Climate Research, Bât. Mercator, 3 Place Louis Pasteur, Louvain-la-Neuve 1348, Belgium.
E-mail address: emilien.aldanajague@uclouvain.be (E. Aldana Jague).

http://dx.doi.org/10.1016/j.still.2015.05.014
0167-1987/

thus generate multiple benefits and a broad range of management strategies have been proposed to increase the storage of organic carbon in soils (Freibauer et al., 2004; Lal 2004).

The identification of rational management strategies as well as the evaluation of their effectiveness requires detailed information on the spatial and temporal patterns of SOC storage. There are several factors influencing the distribution of the SOC content and their relative contribution depends on the spatial and temporal scales under consideration. At the global scale, patterns of SOC are mainly controlled by climatic factors whereby cool and humid regions are characterized SOC-rich soils while hot/cold and dry regions typically contain small amounts of SOC (Stockmann et al., 2013). At the regional scale, the main natural factors influencing the SOC content distribution are soil type, vegetation and the geomorphologic context. At the smaller landscape and/or farm scale, the key factors controlling the variability of SOC are topography, soil and water redistribution processes as well as land-use and management history. In relation to the management strategies discussed above, information is particularly needed at the landscape/farm level: the vertical (i.e., with depth) SOC distribution as well as the effectiveness of management strategies are spatially variable and need to be accounted for (Govers et al., 2013).

However, accurately characterizing the horizontal and vertical variability of SOC (i.e., the spatial variability of the SOC profile) is posing significant challenges. Current soil databases have a very low spatial density as sampling and SOC analysis are time consuming and costly (Govers et al., 2013). In many cases, composite samples are taken without integrating spatial variability. Furthermore, although SOC monitoring is an important component of SOC management (Van Wesemael et al., 2011), changes in SOC are difficult to detect due to the relative slow response of the SOC pool and small absolute changes. A large number of samples are therefore necessary to detect differences in SOC.

So far, most of the studies have focused on the properties and dynamics of SOC stored in the 30 first centimeters of the soil profile (e.g., Bellamy et al., 2005; Goidts et al., 2009). There is now increasing awareness that despite their lower SOC content, most subsoil horizons contribute to more than half of the total SOC stocks (Rumpel and Kögel-Knabner, 2011). The quantification of SOC stocks and changes in SOC stocks for the whole soil profile is

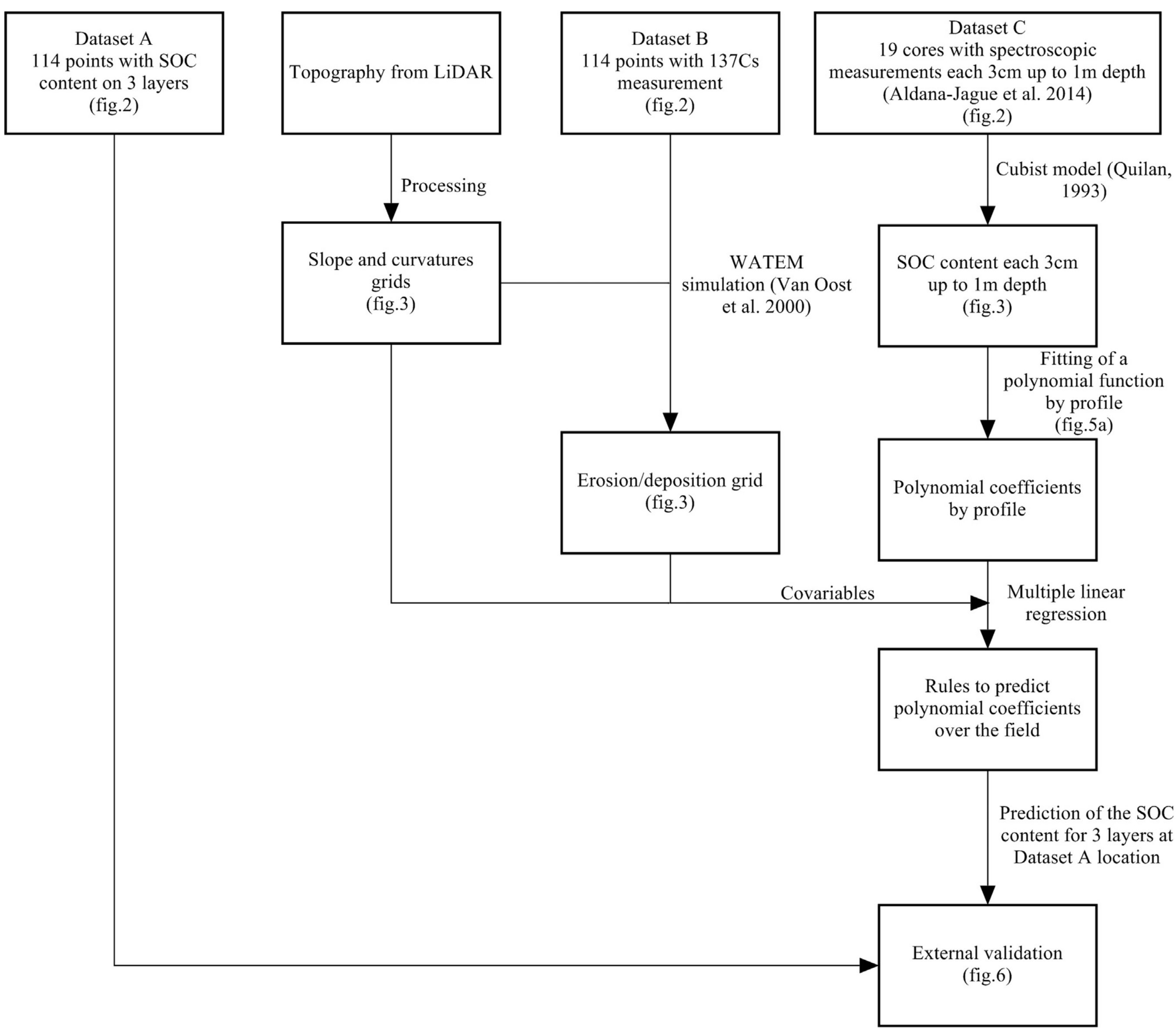

Fig. 1. Flow chart summarizing the methodology steps and datasets used.