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GlobalSoilMap for Soil Organic Carbon Mapping and as a Basis for Global Modeling

Dominique Arrouays[1], Budiman Minasny[2], Alex. B. McBratney[2], Mike Grundy[3], Neil McKenzie[3], James Thompson[4], Alessandro Gimona[5], Suk Young Hong[6], Scott Smith[7], Alfred Hartemink[8], Songchao Chen[1], Manuel P. Martin[1], Vera Leatitia Mulder[9], Anne C. Richer-de-Forges[1], Inakwu Odeh[2], José Padarian[2],Glenn Lelyk[7] Laura Poggio[5], Igor Savin[10], Vladimir Stolbovoy[11], Yiyi Sulaeman[12],Dedi Nursyamsi[12], Gan-Lin Zhang[13], Mogens H. Greve[14], Zamir Libohova[4], Philippe Lagacherie[16], Pierre Roudier[17], Johan G.B. Leenaars[18], Gerard B.M. Heuvelink[18], Luca Montanarella[19], Panos Panagos[19], Jon Hempel[20]*

[1] INRA Orléans, InfoSol Unit, Orléans, France.

[2] The University of Sydney, New South Wales, Australia.

[3] CSIRO, Australia

[4] USDA-Natural Resources Conservation Service, USA.

[5] The James Hutton Institute, Aberdeen, Scotland (UK).

[6] Rural Development Administration (RDA), Republic of Korea.

[7] Agriculture and Agri-Food Canada, Canada.

[8] University of Wisconsin-Madison, Madison, WI, USA.

[9] Wageningen University, Wageningen, The Netherlands

[10] People's Friendship University of Russia, Moscow, Russia.

[11] V.V. Dokuchaev Soil Science Institute, Moscow, Russia.

[12] Indonesian Agency for Agricultural Research and Development, Indonesian Ministry of Agriculture, Bogor, Indonesia.

[13] Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China.

[14] Department of Agroecology, University of Aarhus, Denmark.

[16] INRA, UMR LISAH, Montpellier, France.

[17] Landcare Research, New Zealand.

[18] ISRIC Soil Information, Wageningen, The Netherlands.

[19] European Commission, JRC, Ispra, (VA), Italy

[20] Department of Land Resource Management, Darwin, NT, Australia

Abstract

The demand for information on functional soil properties is high and has increased over time. This is especially true for soil organic carbon (SOC) in the framework of food security and climate change. The *GlobalSoilMap* consortium was established in response to such a soaring demand for up-to-date and relevant soil information. The majority of the data needed to produce *GlobalSoilMap* soil property maps will, at least for the first generation, come mainly from archived soil legacy data, which could include polygon soil maps and point pedon data, and from available co-variates such as climatic data, remote sensing information, geological data, and other forms of environmental information.
Several countries have already released products according to the *GlobalSoilMap* specifications and the project is rejuvenating soil survey and mapping in many parts of the world. Functional soil property maps have been produced using digital soil mapping techniques and existing legacy information and made available to the user community for application. In addition, uncertainty has been provided as a 90% prediction interval based on estimated upper and lower class limits. We believe that *GlobalSoilMap* constitutes the best available framework and methodology to address global issues about SOC mapping. Main scientific challenges include time related and uncertainties issues.

Introduction

The demand for information on functional soil properties is high and has increased over time. This is especially true for soil organic carbon (SOC) due to its major role in climate change mitigation and adaptation and in maintaining and enhancing many soil ecosystem services, among which food production. The *GlobalSoilMap* consortium was established in response to such a soaring demand (Sanchez, et al.; 2009; Arrouays et al., 2014) for up-to-date and relevant soil information. This consortium has undertaken the task of producing soil property maps at a fine resolution (90 m) using digital soil mapping techniques and state-of-the-art and emerging technologies for soil mapping. Many countries have abundant legacy soil data that includes soil maps at a variety of scales, soil point data collected over decades, environmental covariate information and a network of partners that have contributed to building the soil information over many years. In addition, many have some additional soil sites sampled for soil carbon stock and baseline assessment. The majority of the data needed to produce *GlobalSoilMap* soil property maps will, at least for the first generation, come mainly from archived soil legacy data, which could include polygon soil maps and point pedon data (e.g. Leenaars et al., 2014), and from available co-variates such as climatic data, remote sensing information, geological data, and other forms of environmental information. Procedures and methodologies to produce this information vary depending on the types and amount of available data, but all information meet the *GlobalSoilMap* standards and specifications. In this communication, we review the specifications and the state of progress of *GlobalSoilMap* products delivery. We focus on information on SOC and related soil information useful for mapping and modelling SOC and their changes over large areas.

The GlobalSoilMap specifications

The *GlobalSoilMap* project aims to produce a digital soil map of the world. A common set of soil properties at specific resolution with a defined spatial entity, specified depth increments and uncertainty calculations will be available consistently across the globe. The ultimate objective of the project is to build a free downloadable database of key soil properties at multiple depths, mostly using existing soil information and environmental covariates. Maps and data are released both on a 3 arc-sec by 3 arc-second grid on point and block supports. In the first tiers of the specifications, the soil properties are delivered as predictions with uncertainty quantified by means of 90% prediction intervals.

The *GlobalSoilMap* specifications require the estimation of soil property values along with their uncertainty at each of six specified depth increments (0-5, 5-15, 15-30, 30-60, 60-100 and 100-200 cm) for the following soil properties: SOC, clay, silt, sand and coarse fragment contents, pH, ECEC, soil depth and available depth to rooting, bulk density (whole soil and fine earth fraction), and available water capacity. Definitions and methods of analysis of the soil properties are defined in the specifications. As many methods may have been used to measure the soil properties included in the minimum data set they have to be translated to a standard method and the specifications provide guidance on how to do this. The spline function and similar methods are used to transform horizon data into continuous depth functions of soil properties. The estimation of uncertainties is a unique feature but also a major challenge of this project. The uncertainties may determine, for example, whether the soil maps are sufficiently accurate for the intended use or where to conduct new surveys or additional soil sampling to obtain more accurate predictions of soil properties. The *GlobalSoilMap* specifications do not prescribe the methods of prediction, because of diverse soil legacy data situations in various countries. However, Minasny and McBratney (2010) provide a flow chart that outlines different models that can be applied.

GlobalSoilMap **state of progress**

Several countries have already delivered products according to the *GlobalSoilMap* specifications and the project is rejuvenating soil survey and mapping in many parts of the world. Australia and the USA have already released a first complete version of the *GlobalSoilMap* products (Grundy et al. 2015; Viscarra Rossel et al. 2015; Odgers et al., 2012). Some of the most advanced countries include France (Mulder at al. 2016), Denmark (Adhikari et al., 2014), Scotland (Poggio and Gimona, 2014, 2017a &b), Chile (Padarian et al., 2017), Korea (Hong et al., 2010, 2013), Indonesia (Sulaeman et al., 2013) and Nigeria (Akpa et al., 2014). Many other countries (e.g., Canada, Mexico, Iran, China Mainland, Brazil, Argentina, Tunisia, New Zealand, Russia) have developed some trials for part of their territory and/or part of the *GlobalSoilMap* properties. In parallel to these bottom-up approaches from countries, several top-down continental or global predictions have been made, following more or less strictly the *GlobalSoilMap* specifications (Ballabio et al., 2016; Hengl et al., 2015, 2017). In this communication we will present some examples of such products and review their differences according to the data and the model used, their geographical coverage and their uncertainties on SOC predictions.

GlobalSoilMap issues and challenges for SOC

Issues related to time

GlobalSoilMap uses legacy soil data collected over many decades. Data for any point reflect the state of the soil at the time the point was sampled and analyzed. A major challenge for SOC is to reconcile differences in SOC reported for different times and under different land uses to one or more reference dates (e.g. 1990, 2000, 2010) and for each major regional land use type.

Issues related to uncertainty

The evaluation of uncertainty of soil properties prediction is in our view an aspect where most progress is needed. For instance, using *GlobalSoilMap* predictions to run a model of SOC stocks evolution over time requires at least to be able to predict initial SOC stocks and their uncertainties. In this case, these uncertainties come from predictions of various properties (SOC content, coarse element content, bulk density soil depth) and the model itself may require other soil properties (e.g. soil texture, soil available water capacity).

Merging predictions

We think that combining local and global predictions should be the way forward both to enhance the quality of digital soil maps and their use, and to map the entire world. For this purpose both top-down and bottom-up approaches are necessary. In many cases, we feel that bottom-up products better allow to take full advantage of local data and knowledge, and to take into account local soil distribution controlling factors. However, global models have a big advantage in that they avoid spatial gaps and may be a useful tool for harmonizing countries products.

Conclusion

The *GlobalSoilMap* raster based digital soil information will be an essential component in geographic information systems to assist a wide range of users in the decision making process for a range of issues from global to local, one of which being climate change mitigation by SOC sequestration. This information can be produced even with limited background information, but the paucity of data has a strong effect on the uncertainty on predictions. Several countries have already produced maps according to the *GlobalSoilMap* specifications and the project is rejuvenating soil survey and mapping in many parts of the world. We believe that *GlobalSoilMap* constitutes the best available framework and methodology to address global issues about SOC mapping. Main scientific challenges include time related and uncertainties prediction issues.

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