Global Soil Organic Carbon map (GSOCmap) 
v1.6 Technical report
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6.5 SOC stocks by soil type. ........................................ 39
6.6 Comparison of validation criteria between the three SOC products based on international publicly available datasets . .... 43
This document presents the technical details of the first-ever country-driven Global Soil Organic Carbon Map (GSOCmap). This map allows the estimation of Soil Organic Carbon (SOC) stocks from 0 to 30 cm. It represents a key contribution to the Sustainable Development Goal (SDG) indicator 15.3.1, which defines the area of degraded land. The novelty of this map is the fact that it is the first Global SOC stocks assessment which is produced through a participatory approach. Supported by the GSP-Secretariat, countries developed their capacities and stepped up efforts to compile or collect all available soil information at the national level. The 5th GSP Plenary Assembly, in June 2017, approved the decision of Members jointly developing a GSOCmap as a baseline for the amount and distribution of SOC in soils. This map is part of the process of building a Global Soil Information System (GloSIS) under the Soil Information and Data (SID) area of work of the GSP. This considerable effort, which led to the launch of the GSOCmap on World Soil Day 2017 (5 December), is paving the way to the establishment of national soil information systems and represents the first step toward introducing a soil monitoring program.

This technical report is aimed at scientists. It provides guidance on the process that led to the establishment of the GSOCmap and on how to use it. The map provides users with useful information to monitor the soil condition, identify degraded areas, set restoration targets, explore SOC sequestration potentials, support the greenhouse gas emission reporting under the UNFCCC. It also provides users with crucial information that is needed to make evidence-based decisions to mitigate and adapt to climate change.

We can expect that the extensive data content of more than 1 million sampling points resulting from country contributions and the interactive nature of the GSOCmap will greatly assist in the process of building a global soil information system.
system, which in turn will help contribute in the achievement of the SDGs. The contributing institutions from the participating countries which submitted their maps or data are listed in the Appendix.

This technical report is a companion report to the GSOCmap V1.6.0. It presents methodologies and process of compiling the Global Soil organic carbon Map.
Abbreviations and acronyms

BD  Bulk Density
CO₂  Carbon dioxide
CRF  Coarse fragments
DM  Dry matter
DSM  Digital soil mapping
GAUL  Global Administrative Unit Layers
GHG  Greenhouse gas
GSOCmap  Global Soil Organic Carbon Map
GSOCseq  Global Soil Organic Carbon Sequestration Potential Map
GSP  Global Soil Partnership
HWSD  Harmonized World Soil Database
ISCN  International Soil Carbon Network
INSII  International Network of Soil Information Institutions
IPBES  Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC  Intergovernmental Panel on Climate Change
IPR  Intellectual Property Rights
ITPS  Intergovernmental Technical Panel on Soils
LDN  Land Degradation Neutrality
NDVI  Normalized difference in vegetation index
NPP  Net Primary Production
P4WG  Pillar 4 Working Group
QA/QC  Quality Assurance/Quality Check
RMSE  Root mean square error
SDF  Soil Data Facility
SDG  Sustainable Development Goals
SISLAC  Latin America and the Caribbean’s Soil Information System
SOC  Soil organic carbon
SOM  Soil organic matter
SPADE/M  Soil Profile Analytical Database of Europe of Measured Parameters
SWRS  Status of World’s Soil Resources
UNCCD  United Nations Convention to Combat Desertification
WFS  Web Feature Service
WoSIS  World Soil Information Service
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Chapter 1

Background

1.1 The importance of soil organic carbon

Soil organic carbon (SOC) is the main component of soil organic matter (SOM) and is a crucial contributor to food production, mitigation and adaptation to climate change, and the achievement of the Sustainable Development Goals (SDGs). SOC affects most of the processes relevant to soil functions and food production. A high SOM, and therefore SOC content provides plants with the nutrients and water they need by increasing soil fertility and water availability, which in turn improve food productivity. SOC has also long been used as an indicator of soil health, due to its capacity to improve soil structural stability, which affects porosity, aeration and water filtration capacities to supply clean water. However, SOC mineralization can be an important source of greenhouse gas (GHG) emissions. This means that changing SOM (and hence SOC) not only changes the provision of ecosystem services required for crop production, but also affects soils’ capacity to buffer against environmental changes, as it regulates the resilience agricultural systems to climate change.

SOC has received great attention during the development of the greenhouse gas (GHG) reporting programme of the Intergovernmental Panel on Climate Change (IPCC) since the mid-nineties. This was done to address the contribution of intensive land management and the vast amount of degraded land to greenhouse gas emissions, since these have caused tremendous historic losses of SOC, resulting in high potentials for future carbon storage. Recently, an
increasing number of authors have stressed the crucial role of healthy soils, with soil carbon being the most important indicator for food security and resilience against climate change. This has led to above and below ground carbon (SOC) becoming sub-indicators for the Sustainable Development Goals (SDG) target 15.3.1 (Proportion of land that is degraded over total land area).

The Status of the World’s Soil Resources (SWRS) report highlights that, although more carbon is stored in the soil than in the atmosphere and plant life combined, a large portion (33 percent) of the world’s soils are degraded, which has led to a major loss of global SOC reserves. The reversal of soil degradation through the buildup of SOM and the sustainable management of soils therefore offers large potential to contribute to climate change mitigation by sequestering atmospheric carbon into the soil. This emphasizes that soil can be a double-edged sword when it comes to carbon fluxes, as it can either be a net sink or a net source of GHGs depending on soil management practices.

Despite the current focus on SOC, knowledge about SOC baselines and changes, and the detection of vulnerable hot spots for SOC losses and gains under climate change and changed land management are still fairly limited. Accurate SOC baselines are still needed for many countries, and estimates about the role of soils in the global carbon cycle are currently only based on rough estimates, which results in large uncertainties. Global SOC estimates exist, but there is high variability in reported values among authors, caused by the diversity of different data sources and methodologies used to calculate and measure these estimates (Henry et al., 2009; Köchy et al., 2015).

### 1.2 Objectives of soil organic carbon mapping

The Intergovernmental Technical Panel on Soils (ITPS) and the GSP Secretariat were asked by the Science-Policy Interface (SPI) of the United Nations Convention to Combat Desertification (UNCCD) to share information about the possible pathways to support the SDG 15.3.1 indicator on SOC. During the fifth Session of the ITPS held during March 2016, collaboration between the ITPS and the SPI of the UNCCD, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and the Intergovernmental Panel on Climate Change (IPCC) was discussed. The GSP/ITPS were requested to conduct a global SOC assessment based on country-level spatial soil data sets, combined into a new global SOC map. This task would directly relate to SDG 15.3.1, and
would also support the endorsed metrics for the assessment of land degradation neutrality (LDN) (ITPS & FAO, 2015). The preparation of the GSOCmap was discussed and supported to the fourth and fifth GSP Plenary Assembly (FAO & GSP, 2016; FAO & GSP, 2017a).

As it was approved by the decision of the 5th GSP Plenary Assembly, June 2017 (FAO & GSP, 2017), GSP members agreed to jointly develop a global SOC map as the zero status for the amount and distribution of SOC in soils around the world. This map was developed following the general GSP principle of being a country-driven initiative. It is a part of the process to build a Global Soil Information System under GSP Pillar 4 (Enhance the quantity and quality of soil data and information: data collection (generation), analysis, validation, reporting, monitoring and integration with other disciplines).

The development of a global soil organic carbon map using a country-driven approach provides and builds on synergies with ongoing and new reporting needs, data sharing obligations, and therefore benefits activities at national, regional and global levels. Particularly to:

- enable training for countries in need of technical support (e.g. regarding the collection, statistical evaluation and modeling of SOC data);
- develop data infrastructure to update the SWRS report on SOC through a country-driven baseline, and initiate future assessments of SOC changes;
- support national GHG reporting: develop a valid, measurement-based inventory of reference SOC stocks for IPCC-Tier 2 assessments;
- further utilize SOC mapping to estimate the soil carbon sequestration potentials (e.g. through modeling) and the vulnerability of soil functions under climate change (with SOC as an indicator);
- contribute to the Sustainable Development Goals: by developing national SDG-15.3.1 Tier 3 data for the sub-indicator of soil carbon; and
- conduct harmonized assessments at different levels of action: GSP regional soil partnerships, FAO regional and country offices, national soil information institutions (GSP Pillar 4 INSII), national statistics offices (already involved with FAOSTAT), and GEOSS design principles for global data layers.
1.3 Data policy

1.3.1 Data sharing principles

The GSP Data Policy has been endorsed by partners of the Global Soil Partnership during the 5th GSP Plenary Assembly in June 2017 (GSP & FAO, 2017) in order to promote and govern soil data sharing for data products including GSOCmap contributions, and considering harmonization and interoperability requirements.

The GSP data policy aims to ensure that:

- every existing ownership right to shared soil data are respected;
- the specific level of access and the conditions for data sharing are clearly specified;
- the ownership of each dataset and web service are properly acknowledged and well-referenced; and
- the data owners are protected from any liability arising from the use of their original and/or derived data.

It is recommended that data owners comply with the following open data principles:

1. Accessibility: the data shall be divulged through the Internet (web services).
2. Availability: the data is presented in a convenient, platform-independent, and in line with standard formats (e.g. web feature service WFS).
3. License: the formal concession of the usage and access rights over the data shared.
4. Cost: data shall be shared free of cost, or at no more than a reasonable reproduction cost, preferably by downloading it from the Internet.
5. Re-use and Redistribution: data must be provided and licensed under terms that permit its reuse and redistribution, including intermixing with other datasets.
6. Global benefit: any user must be able to access, use and redistribute data of the Global Soil Information System. However, inherited restrictions by national data policies shall be accepted.

7. Metadata: data describing the products of the Global Soil Information System will by default be open for access.

The data shared by the countries shall contain the relevant soil information representative for the area portrayed. The shared datasets contain the best available information for a given area and topic, however, they are subject to potential restrictions based on the institutions’ or countries’ data policy. The data shared by the countries should be quality controlled which means that the data have been technically evaluated to ensure data integrity, correctness, and completeness; errors and omissions are identified and, if possible, addressed.

1.3.2 Ownership, data rights and citation

In the case of original data, the rightful data owner keeps full ownership of it. All intellectual property rights (IPR) and copyrights pertaining to the data owner remain intact and are respected by the soil data facility (SDF) host. All data providers must communicate to the SDI host their IPR and data use policies. Thus, the ownership of all data made available through the GSP soil portal need to be clearly specified. This is an important prerequisite to allow this data to be accessible through the soil SDF.

In the case of derived data, the deriving institution becomes the rightful owner. However, all original data must be accredited and correctly cited. According to the Pillar 4 Implementation Plan, each global-level derived GSP data product will be quality-assured by the Pillar 4 Working Group. This includes agreements about the correct citation.

The data owner shall ensure that the data shared can be used and interpreted by the authorized users in general; this includes providing the proper citations, as well as providing information over the ownership of such data for acknowledgement purposes. Users shall acknowledge the source of data provided through the Global Soil Information System.

All providers of original data (data owners) are responsible to define and clarify the IPR and licensing. Any user of this data, such as the SDF host, has to respect the national data policies and/or licensing involved with the retrieval of
the respective web services. In the case of data provided to the central repository, a bilateral agreement/license may be required (between the national data owner and SDF host), depending on and in conformity with national rules. More information about the data policy can be accessed at GSP & FAO (2017).
Chapter 2

GSP capacity development programme

2.1 Training courses on digital soil mapping

Considering the request from partners to support them by providing training on state of the art techniques for SOC mapping, the Secretariat designed a capacity development programme following an on-the-job training model. The aim of the GSP capacity development program has been to introduce recent concepts and techniques of digital soil mapping (DSM) to soil experts who work at national soil science institutes in soil mapping related activities. The impact of the trainings should be reflected on developing and updating national and regional soil information systems.
In order to support national capacities on digital soil organic carbon mapping, DSM workshops were organized by the GSP and the regional soil partnerships. The training workshops were already part of the GSP capacity development programme before the launch of the GSOCmap project (2012–2016). In 2017, the training focused more on digital soil organic carbon mapping to support countries with their GSOCmap contributions. After the launch of the GSOCmap project, additional training sessions were organized in different regions and eventually the capacity development programme was able to reach 105 countries and 60 percent of the area coverage (see Figure 2.1).

The contents of the workshops included: introduction to R; preparing spatial covariates using SAGA GIS; correlation analysis; regression–kriging; random-Forest; support vector machines; uncertainties and validation. By the end of the training courses, participants were able to collect and rescue soil legacy data, compile and harmonize soil data for DSM applications, implement DSM, produce soil property maps and their uncertainties, and develop accurate digital soil maps for updating their national soil information systems.
2.2 GSP remote support platform

There was a systematic support of the GSP Secretariat to assist and provide technical support to soil experts after the training sessions (e.g., phone, video conferencing, email exchange). The post-training support process allowed the GSP Secretariat to address any questions, doubts, or problems that countries faced.

2.3 Soil organic carbon mapping cookbook

The soil organic carbon mapping cookbook (Yigini et al., 2018) has been developed by the ITPS and GSP Secretariat to provide generic methodologies and the technical steps for producing a SOC map. This includes step-by-step guidance for developing 1 km grids for SOC stocks, as well as for the preparation of local soil data, the compilation and pre-processing of ancillary spatial data sets, mapping methodologies, and uncertainty assessments. Guidance is mainly specific to soil organic carbon data, but also contains many generic sections on soil grid development due to its relevance for other soil properties. The main focus of the guidance is on the mapping of SOC stocks in the GSOCmap and as such the cookbook supplements the GSP Guidelines for sharing national data/information to compile a Global Soil Organic Carbon (GSOC) map. It provides technical guidance to:

- setting up the needed software environment;
- preparing ground data for soil organic carbon modelling;
- calculating SOC stocks from local samples to a target depth of 30 cm;
- preparing spatial covariates for mapping;
- choosing and applying the best suitable mapping methodology; and
- evaluating the results and the outputs and providing guidance on validation and uncertainty assessments.
2.4 GSP and ISRIC environmental covariates data repository

A set of standardized national environmental covariates for digital soil mapping were provided by ISRIC World Soil Information (Table 2.1). The data can be accessed through ftp, all necessary credentials have been provided to the countries. The provided data sets fall within the following thematic fields:

- geomorphometry i.e. digital elevation models and derived land surface parameters and objects;
- spectral and multispectral remote sensing imagery and derived parameters;
- climatic and meteorological covariates;
- land cover/land use information; and
- parent material and soil-unit maps.

This data repository contains GIS raster layers of various biophysical earth surface properties for each territory in the world. These layers can, for example, be used as covariates in a digital soil mapping exercise. The territories and their boundaries are obtained from from the Global Administrative Unit Layers (GAUL) dataset.

Each folder contains three sub-folders:

- covs: GIS layers of various biophysical earth surface properties; and
- mask: an ‘empty’ grid file of the territory with territory boundary according to GAUL. This grid can for instance be used as a mapping mask.

Data Specifications
File format: GeoTiff
Coordinate system: WGS84, latitude-longitude in decimal degrees
Spatial resolution: 1 km

Data Access: https://files.isric.org/projects/gsp/ (user: gsp, pwd: gspisric)

Licence and Acknowledgement
The GIS layers can be freely used under the condition that proper credit should be given to the original data source in each publication or product derived from these layers. Licences, data sources, and data citations are indicated in the data description table.
Table 2.1: Covariates.

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<td>SD monthly MODIS LST (nighttime) Oct</td>
</tr>
<tr>
<td>N11MSD3</td>
<td>MOD11A2</td>
<td>SD monthly MODIS LST (nighttime) Nov</td>
</tr>
<tr>
<td>N12MSD3</td>
<td>MOD11A2</td>
<td>SD monthly MODIS LST (nighttime) Dec</td>
</tr>
<tr>
<td>TMDMOD3</td>
<td>MOD11A2</td>
<td>Mean annual LST</td>
</tr>
<tr>
<td>TMNMOD3</td>
<td>MOD11A2</td>
<td>Mean annual LST (daytime) MODIS</td>
</tr>
<tr>
<td>P01CHE3</td>
<td>Global precipitation</td>
<td>Mean monthly precipitation at 1 km Jan</td>
</tr>
<tr>
<td>P02CHE3</td>
<td>Global precipitation</td>
<td>Mean monthly precipitation at 1 km Feb</td>
</tr>
<tr>
<td>P03CHE3</td>
<td>Global precipitation</td>
<td>Mean monthly precipitation at 1 km Mar</td>
</tr>
<tr>
<td>P04CHE3</td>
<td>Global precipitation</td>
<td>Mean monthly precipitation at 1 km Apr</td>
</tr>
<tr>
<td>P05CHE3</td>
<td>Global precipitation</td>
<td>Mean monthly precipitation</td>
</tr>
</tbody>
</table>
Chapter 3

Product specifications

3.1 Generic target specification

A global layer of harmonized national soil carbon stock maps has been developed according to the following specification:

- grid at 30 arc-seconds resolution (approximately 1 x 1 km). Generic grid has been provided by ISRIC World Soil Information;
- various SOC analysis methods and measurements are acceptable;
- 0–30 cm depth, including national increments and/or higher (deeper) depths where applicable;
- SOC stock [t/ha], bulk density (BD) [kg/m$^3$] and stone content [percent] can be estimated or measured; and
- mapping/upscaling: various approaches possible (including country-specific stratification and custom resolution finer than 1 x 1 km).

More information about the product specification can be accessed at FAO & GSP (2017b).
3.2 Metadata specifications

In order to ensure that the national layers metadata would be sufficient for quality assessment and possible harmonization, the countries were required to share information about their original data according to the following principles:

1. Share auxiliary information about the national data sources, e.g. type of sampling (soil profile or auger), density of sampling points in the country, sampling design (distribution and sampling depth/s), time of sampling (year), selection criteria (if subset of soil profiles is selected from a larger national database).

2. Provide as much metadata as possible in order to estimate the quality of the global SOC map. For example, SOC method(s) of analysis.

3. Share metadata about SOC stocks calculation in terms of:
   - describing how SOC stocks for the target depth 0–30 cm have been calculated; if there are any deviations from this specification, provide an explanation;
   - quantifying the amount of carbon stored in litter (organic layer of forest floors);
   - if data allow, stratifying the national soil databases according to organic (peat) and inorganic soils, and estimate the SOC stock for peat soils to 1 m depth;
   - providing a description of the method used for bulk density measurements or estimations; and
   - providing a description of the method used for coarse fragments measurements or estimations.

4. Share details about the upscaling approach:
   - mapping method (description, citation); and
   - input data/covariates, grid, soil maps, etc.

5. In order to consider the temporal dimension of the SOC map, it is important to share the sampling date as metadata. If the national data situation allows, pre-1990 or post-1990 sub data sets might be defined. However, it
will be an important asset of this SOC map to demonstrate the density of existing soil carbon data sets. The more data points are used, the better the reliability and accuracy of the global product. Subsequent steps to improve the temporal dimension, will be considered at a later stage.
Chapter 4

Data collection and processing

4.1 Different scenarios of country driven action

The GSP Secretariat facilitated the process where countries were asked to deliver the following data and information:

- national soil organic carbon stock map;
- uncertainty assessment a) qualitative assessment (conventional mapping) and/or b) quantitative (digital soil mapping);
- metadata: The data shared by the counties are extensively documented to enable quality and uncertainty assessments. This will allow insights into the quality of the SOC maps, remaining gaps and harmonization needs. Countries were required to provide detailed metadata documented in the GSOCmap guidelines (FAO & GSP, 2017b); and
- one-page report: A brief report describes the current status of the national SOC data, data collection, preparation and harmonization efforts, selection of the method(s), challenges and assessment of the results.
4.1. Different scenarios of country driven action

The GSP Secretariat organized the data collection depending on national capacities, data availability/usability (Figure 4.1):

- country submissions: Countries produced and delivered their GSOCmap contributions to the GSP Secretariat;
- joint efforts: The GSP Secretariat worked with the soil experts from the Members to produce their GSOCmap contributions; and
- GSP gap-filling: The Secretariat produced or used publicly available point or raster data for the countries that were not able to contribute to the current version of the product.

4.1.1 Delivery of the maps produced by the countries

The GSP Secretariat contacted countries about their potential contributions to the GSOCmap project and informed countries about the process and the procedure.
Countries already having national SOC maps that meet the specifications of this project, shared their data with the GSP Secretariat. If a national SOC map exists, and if not all requirements were met, adjustments to the existing SOC map were implemented (e.g. recalculation according to target depth). Countries which did not yet have a national SOC map, developed such a map based on the specifications. Where needed, the GSP Secretariat supported such national activities by organising training sessions. Upon receiving the national maps, the GSP Secretariat undertook the preliminary data quality checks. Whenever the national maps were inconsistent with the GSOC specifications, the GSP Secretariat worked in close collaboration with the institutions that provided the national data to resolve the existing issues. 76 countries submitted their maps as a contribution to the GSOCmap. This represents 65 percent of the world area (Table 4.1).

4.1.1.1 Data submission form

To deliver their data, countries were required to use the online data submission tool. The tool realized a guided delivery process which required the submitter to upload the map along with a one-page report, and to answer questions about the methodology according to the metadata specifications. The questionnaire can be found in Annex A. This questionnaire and the report were used to create the country-specific metadata for the map. A summary of this data can be found in Annex D and chapter 5.

4.1.2 Joint efforts

If the in-country development of a SOC map was not possible due to insufficient capacity, the original SOC measurements were shared with the GSP secretariat which would then execute the mapping in close cooperation with the national GSP–focal points and/or institutional data providers. For the mapping, the GSP Secretariat used state-of-the-art digital soil mapping techniques and publicly available layers of environmental covariates (ISRIC, ftp service). The data were then evaluated by the national experts who made the final decision regarding the results of the joint mapping procedure and the final submission of the map. 8 country maps were prepared with joint efforts between the GSP and the countries (Table 4.1).
4.1.3 GSP gapfilling

For the countries that could not provide a SOC map or any original measurements, the GSP Secretariat used one of the two gap-filling approaches: spatial modeling using publicly available data or, in the case of absence or insufficient amount of data, using publicly available SOC stock maps.

The gap filling procedure involved producing maps for 108 countries. 69 country maps (26.4 percent of the world area) were done using available data; and 39 country maps (1.0 percent of the world area) were filled using external datasets (e.g. soilgrids.org data).

Table 4.1: Sources of the country maps included in the GSOCmap v1.6

<table>
<thead>
<tr>
<th>Contribution</th>
<th>n</th>
<th>Area sqkm</th>
<th>Percent of world area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country submission</td>
<td>74</td>
<td>83 821 626</td>
<td>64.8</td>
</tr>
<tr>
<td>Joint effort with GSP</td>
<td>13</td>
<td>10 029 039</td>
<td>7.8</td>
</tr>
<tr>
<td>GSP gap-filling</td>
<td>69</td>
<td>34 183 499</td>
<td>26.4</td>
</tr>
<tr>
<td>External dataset: soilgrids.org</td>
<td>39</td>
<td>1 304 964</td>
<td>1.0</td>
</tr>
</tbody>
</table>

4.1.3.1 Spatial modeling using publicly available data

For the countries where publicly available data of SOC measurements were sufficient for SOC mapping, the GSP Secretariat used digital soil mapping techniques to create the maps. The following data sources used for this purpose:

- WOSIS (Batjes et al., 2017);
- LUCAS soil (European Union – EU27) (Toth et al., 2013); and
- AfSIS (Africa Soil Information Service) (Walsh et al., 2009).

Publicly available layers of environmental covariates (WorldGrids.org currently available at https://zenodo.org/record/1637816#.XP4tXogzbiU and https://gitlab.com/openlandmap) were used for the spatial modeling. Example scripts similar to the ones used by the GSP for building these maps can be found in Annex C.
4.2. Data processing and compilation of the GSOCmap

4.1.3.2 Using publicly available SOC stock maps

For the countries lacking any publicly available data of SOC measurements (around 1.4 percent of the global coverage), the maps were produced using SoilGrids 250m product (Poggio et al., 2021) resampled according to the GSOC specifications.

4.2 Data processing and compilation of the GSOCmap

In order to compile a Global Soil Organic Carbon Map from the national contributions, the GSP Secretariat conducted basic data processing aimed to standardize the individual layers with minimal or no changes to the data provided by the countries. The processing steps included:

- reprojecting data to coordinate system lon/lat WGS84 with spatial resolution of 30 arc-second using ‘nearest neighbour’ method (where necessary);
- resampling the data to 30 arc seconds grid resolution using bilinear interpolation (in case the cell size of the original data was different);
- converting SOC stock values to tonnes/ha (where necessary);
- mosaicking individual maps of the countries to acquire the global layer using ‘nearest neighbour’ method for resampling;
- filling NoData values at national borderlines (in case the countries didn’t use suggested empty grids) using GDAL gapfilling algorithm which interpolates values for all designated NoData pixels using inverse distance weighting and a four direction conic search to find values to interpolate from. A mask compiled from a 5-km buffer around country borders (excluding water bodies and coastlines) was used as a gap–filling procedure in order to make sure that only border gaps are filled and the NoData values provided by countries because of lack of information are preserved; and
- applying a global mask of water bodies (World Water Bodies, Esri, Garmin International).
Chapter 5

Metadata

The GSOCmap is a compilation of soil organic carbon stock maps produced by the countries in accordance with the GSOCmap guidelines (FAO & GSP, 2017b). The total number of profiles/sampling locations used to create the global product is: 1 079 617. The number of sampling plots was calculated from the meta–data provided by the Members.

5.1 Sampling density

The metadata allows to assess the density of sampling points per country as shown in Figure 5.1. It varies greatly and reflects the differences in the soil data coverage between countries and regions. This information can be used as an assessment of the current status of the available soil information in the world and to identify the regions where additional sampling is most needed.
5.2 Temporal dimension

The metadata on the period of sampling was analyzed against the suggested baseline date 1990. 11 percent of the countries did not provide information about the temporal dimension. Besides, data about the temporal dimension for the 25 percent of the countries with data from external datasets, like soilgrids.org, were not available. The other 65 percent is divided: 15 percent with data from before 1990; 25 percent with a mix of data before and after 1990 and only 25 percent with all the data surveyed after 1990.

The results show that most countries had to include observations from before 1990 to develop a dataset representing all their territory (Figure 5.2). This means that the GSOCmap can be used as a baseline for SOC monitoring only for the countries with all the submitted data originating from recent soil surveys. However, the GSOCmap can be viewed as a baseline map, as it contains the best available estimation of SOC at the country level (see Validation and comparison with existing products), making it an important tool for identifying SOC deficient areas within the countries and subsequently for planning the soil–protecting, sampling and monitoring activities.

Figure 5.1: Density of point data (per country). Source: UN Geospatial, 2020, modified by authors.

However, aggregation of the data at the country level does not allow to accurately represent the sampling density in case of uneven distribution.
Concerning the SOC analysis method, 42 percent of the countries used wet oxidation, and 14 percent used dry combustion. The number of countries using soil spectroscopy is less than 1 percent.

The metadata shows differences in the methods used throughout the world for determining SOC (Figure 5.3). This is valuable information for investigating the possibility of further harmonization of national data. One of the known issues is the difference in measured carbon values between Ethiopia and the surrounding countries, which could be caused by the difference in SOC analysis method since Ethiopia was the only country to use soil spectroscopy measurements as its primary data source.
5.4 Bulk density

Measurements of bulk density were not available in many countries, thus different strategies were used to overcome this limitation (Figure 5.4).

1. Using nationally developed pedotransfer functions.
3. Using the values from publicly available datasets (such as Harmonized World Soil Database (FAO, 2012) and SoilGrids (Hengl et al., 2017)).
Only 8 percent of the countries used only measured bulk density data to estimate the soil organic carbon stock. 27 percent submitted measured values for some profiles, but had to use pedotransfer functions for others. 28 percent relied only on pedotransfer functions. And external datasets like soilgrids.org or the HWSD were used for 28 percent of the countries. 9 percent of the countries did not provide information about the source of their bulk density data.

The estimation of bulk density is a potential source of high uncertainty in the calculation of carbon stocks, especially in soils with high stoniness (Poeplau et al., 2017). According to our findings, more than 55 percent of the countries used pedotransfer functions, but only 25 percent used locally fitted pedotransfer functions. With a high percentage of countries using the pedotransfer functions suggested in Yigini et al. (2018).
5.5 Coarse fragments

Figure 5.5: Coarse fragments methods. Source: UN Geospatial, 2020, modified by authors.

The metadata show that the majority of the countries had limited data on the coarse fragment content which could be a source of uncertainty in the calculation of organic carbon stocks, especially in mountainous areas (Figure 5.5). Only 17 percent of the countries had measured data for the amount of coarse fragments. 10 percent used estimated values and 7 percent used a mix between estimated and measured values. Almost 40 percent of the countries did not use any information about the coarse fragments fraction for the organic carbon stock estimation.

5.6 Mapping methods

Various mapping methods were used by the countries depending on the capacity, data availability, and the specific features of the local soil cover, including but not limited to:

- conventional upscaling: geo-matching, class-matching;
5.6. Mapping methods

- digital soil mapping methods: Multiple linear regression, regression kriging, multivariate adaptive regression splines, generalized linear models, generalized additive models, etc.;

- machine learning techniques: Random forest, support vector machine, neural networks, regression trees, bayesian trees, etc.;

- ensemble models combining different DSM methods; and

- geostatistical methods: Ordinary kriging, IDW.

Figure 5.6: Mapping methods. Source: UN Geospatial, 2020, modified by authors.

Figure 5.6 shows that most countries (66 percent) were able to use the state–of–the–art digital soil mapping techniques which demonstrates the overall success of the capacity building program undertaken by the FAO/GSP. Only 7 percent of the countries used conventional upscaling.

The heterogeneity of the mapping techniques could be one of the sources of uncertainty and ‘border effects’ between national products. However, the map shows that the difference in mapping methods is not the primary source of border inconsistency. As shown in the Figure 5.7, in many cases, the maps produced with different mapping methods have comparable values and form a continuous surface of organic carbon distribution with acceptable differences. Besides, there is no best mapping method for digital soil mapping, and testing and selection has to be done for every data scenario (FAO & GSP, 2017b).
The primary source of uncertainty and border inconsistencies appears to be in the original point data quality and representativity. The difference at the borders between the countries occurs when the adjacent region is not covered with soil sampling data and the values are extrapolated using a model from a different area or assigned on the basis of expert knowledge. Therefore, it is suggested that the work on improving the global consistency should be primarily focused on acquiring additional data in the under sampled regions and capacity development aimed at ensuring that an appropriate mapping method was used based on the data distribution and representativity.
Chapter 6

Results

6.1 Total global soil organic carbon stock

Figure 6.1: GSOCmap version 1.6.0.

Global soil organic carbon stock for topsoil (0 to 30 cm) is 682 Petagrams. This value is 2.4 percent lower than the value for the HWSDa (Köchy et al.,
6.1. Total global soil organic carbon stock

2015) (Table 6.1).

Table 6.1: Global SOC estimates.

<table>
<thead>
<tr>
<th>GSOCmap</th>
<th>HWSD</th>
<th>HWSDa</th>
<th>FAO2007</th>
<th>WISE</th>
<th>DSMW</th>
<th>soilgrids 250m</th>
</tr>
</thead>
<tbody>
<tr>
<td>682</td>
<td>967</td>
<td>699</td>
<td>710</td>
<td>504</td>
<td>574</td>
<td>1 267</td>
</tr>
</tbody>
</table>

6.1.1 Statistics for countries (GSOCmap V 1.6.0)

Statistics for the countries were calculated based on the global administrative units layer as the source for country boundaries. Over 70 percent of the global SOC stocks at 30 cm is held by 14 countries: the Russian Federation, Canada, the United States of America, China, Brazil, Indonesia, Australia, Argentina, the Democratic Republic of the Congo, Kazakhstan, Peru, Mongolia, Chile, and India (Table 6.2). Among these countries, Indonesia and Chile have the highest mean SOC stocks (103.6 and 71.8 t/ha respectively).

Table 6.2: SOC stocks for selected countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>SOC stock (Pg)</th>
<th>Mean SOC (t/ha)</th>
<th>Global share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russian Federation</td>
<td>147.0</td>
<td>36.7</td>
<td>21.6</td>
</tr>
<tr>
<td>Canada</td>
<td>80.2</td>
<td>37.9</td>
<td>11.8</td>
</tr>
<tr>
<td>United States of America</td>
<td>54.0</td>
<td>34.9</td>
<td>7.9</td>
</tr>
<tr>
<td>China</td>
<td>44.8</td>
<td>33.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Brazil</td>
<td>35.1</td>
<td>34.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>22.5</td>
<td>103.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Australia</td>
<td>22.5</td>
<td>22.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Argentina</td>
<td>13.7</td>
<td>34.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>12.3</td>
<td>45.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>11.9</td>
<td>25.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Peru</td>
<td>10.0</td>
<td>65.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Mongolia</td>
<td>8.1</td>
<td>30.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Chile</td>
<td>7.8</td>
<td>71.8</td>
<td>1.1</td>
</tr>
<tr>
<td>India</td>
<td>7.5</td>
<td>20.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>
6.1.2 Statistics for climate zones, land use and soil types

To estimate the relationship between SOC and climate, the result layer was spatially intersected with the IPCC, 2006 climate regions layer. The zones are defined by a set of rules based on annual mean daily temperature, total annual precipitation, total annual potential evapotranspiration (PET) and elevation. The largest carbon pool is located in the boreal moist zone followed by the Cool Temperate Moist zone (Table 6.3). To show the relation between below ground and above ground organic carbon stocks, SOC stocks per IPCC climate region were compared to aboveground organic carbon stocks derived from IPCC (2008) (Figure 6.3).

Table 6.3: SOC stocks by IPCC climate region.

<table>
<thead>
<tr>
<th>IPCC Climate Region</th>
<th>SOC stock (Pg)</th>
<th>Mean SOC (t/ha)</th>
<th>Global share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boreal Moist</td>
<td>143.0</td>
<td>40.1</td>
<td>21.0</td>
</tr>
<tr>
<td>Cool Temperate Moist</td>
<td>97.7</td>
<td>45.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Tropical Moist</td>
<td>86.3</td>
<td>46.3</td>
<td>12.7</td>
</tr>
<tr>
<td>Subtropical Moist</td>
<td>56.5</td>
<td>45.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Cool Temperate Dry</td>
<td>51.3</td>
<td>28.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Warm Temperate Moist</td>
<td>42.4</td>
<td>42.1</td>
<td>6.2</td>
</tr>
<tr>
<td>Boreal Dry</td>
<td>40.0</td>
<td>38.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Subtropical Dry</td>
<td>36.7</td>
<td>21.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Tropical Dry</td>
<td>32.6</td>
<td>19.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Warm Temperate Dry</td>
<td>31.3</td>
<td>22.1</td>
<td>4.6</td>
</tr>
<tr>
<td>Polar Moist</td>
<td>28.7</td>
<td>29.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Polar Dry</td>
<td>13.5</td>
<td>32.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>
The same approach was used to compare the GSOCmap to land cover data. The land covers were based on is the reclassified GlobCover 2009 map (Arino et al. 2009). The following land cover classes were considered: cropland, forest, grassland, wetland and other and reclassified from the from the Globcover classes (Table 6.4). The greatest share of SOC is found within forests (298.8 Pg, 43.1 percent) followed by grasslands (179.4 Pg, 25.9 percent) and croplands (143.4 Pg, 20.7 percent). The greatest mean SOC stocks in t/ha are found in wetlands with 95.4 t/ha.
Table 6.4: SOC stocks by land cover.

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>SOC stock (Pg)</th>
<th>Mean SOC (t/ha)</th>
<th>Global share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>291.6</td>
<td>42.1</td>
<td>42.8</td>
</tr>
<tr>
<td>Grasslands</td>
<td>178.2</td>
<td>30.1</td>
<td>26.1</td>
</tr>
<tr>
<td>Croplands</td>
<td>140.1</td>
<td>35.7</td>
<td>20.5</td>
</tr>
<tr>
<td>Others</td>
<td>46.7</td>
<td>14.8</td>
<td>6.9</td>
</tr>
<tr>
<td>Wetlands</td>
<td>24.0</td>
<td>47.8</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The relationship with soil types was explored using the Harmonized World Soil Database (HWSD) (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012). The HWSD is a 30 arc-second raster database with over 16 000 different soil mapping units that combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 1971–1981). Although the soils richest in organic carbon are Histosols, Gleysols, Andosols and Chernozems, most of the carbon in the world is stored in Leptosols and Cambisols due to their larger area coverage (Table 6.5).
Table 6.5: SOC stocks by soil type.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>SOC stock (Pg)</th>
<th>Mean SOC (t/ha)</th>
<th>Global share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptosols</td>
<td>78.7</td>
<td>38.8</td>
<td>11.5</td>
</tr>
<tr>
<td>Cambisols</td>
<td>65.8</td>
<td>46.0</td>
<td>9.7</td>
</tr>
<tr>
<td>Gleysols</td>
<td>60.3</td>
<td>41.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Podzols</td>
<td>56.0</td>
<td>45.6</td>
<td>8.2</td>
</tr>
<tr>
<td>Acrisols</td>
<td>45.2</td>
<td>26.9</td>
<td>6.6</td>
</tr>
<tr>
<td>Regosols</td>
<td>44.5</td>
<td>40.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Ferralsols</td>
<td>39.8</td>
<td>30.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Luvisols</td>
<td>36.2</td>
<td>63.8</td>
<td>5.3</td>
</tr>
<tr>
<td>Histosols</td>
<td>34.6</td>
<td>19.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Arenosols</td>
<td>24.1</td>
<td>15.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Calcisols</td>
<td>21.3</td>
<td>49.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Chernozems</td>
<td>19.6</td>
<td>34.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Fluvisols</td>
<td>19.4</td>
<td>41.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Phaeozems</td>
<td>18.3</td>
<td>28.6</td>
<td>2.7</td>
</tr>
<tr>
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6.2 Validation, uncertainty and comparison with existing products

6.2.1 Validation of the GSOCmap using available data

The spatial distribution of soil organic carbon (SOC) represents one of the largest uncertainties in the carbon cycle (Figure 6.4). High resolution gridded datasets of SOC are increasingly important for global modeling efforts and validation strategies (Jackson et al., 2017). Validation experiments (e.g. across borders), the comparison of different approaches to predict soil carbon and the continuous calibration of country-specific to regional to global models are required to provide reliable estimates and enable the monitoring of SOC stocks.
6.2. Validation, uncertainty and comparison with existing products

To compare and test different approaches (e.g. modeling and geo-matching), to map SOC stocks is relevant to reduce the current levels of uncertainty regarding the spatial variability and distribution of SOC, because they will work differently for the same objective. Using the same dataset, different approaches to map SOC will share bias derived from the quality of the data and the data characteristics that allow to meet modeling assumptions, or provide certainty to the soil mapper delineating a soil carbon polygon unit.

The validation of the map was done by comparison with available soil profile data and the existing global SOC products. First, a validation dataset was compiled from international publicly available datasets, in particular the International Soil Carbon Network (ISCN) (Nave et al., 2017; Boby et al., 2010; Bockheim et al., 2003; Bockheim et al., 2010; Buell et al., 2004; Camill

Figure 6.3: Comparison between different estimates of global SOC stocks in topsoils
Validation, uncertainty and comparison with existing products

et al., 2009; Cole et al., 2013; Harden et al., 1999; Harden et al., 2012; Johnson et al., 2011; Jorgenson et al., 2009; Kane et al. 2009; Manies & Survey, 2004; Myers-Smith et al., 2007; O’Donnell et al., 2011; Ping & Liang, 2011; Tarnocai et al., 2009; Trumbore et al., 1999; Zinke et al., 1986) including extensive data contributions to the ISCN from the USDA Natural Resources Conservation Service, National Cooperative Soil Survey (Soil Survey Staff, 2014); World Soil Information Service (WoSIS) (Batjes et al., 2017), soil organic carbon stock estimates with uncertainty estimation across Latin America (Guevara et al., 2019), Latin America and the Caribbean’s Soil Information System (SIS-LAC)(GSP, 2013), the Northern Circumpolar Soil Carbon Database (Hugelius et al., 2013) and Soil Profile Analytical Database of Europe of Measured parameters (SPADE/M) (Hiederer et al., 2006). From these databases only the profiles with measured SOC and bulk density values were selected, since these parameters are essential for calculating SOC stocks – 50 708 points in total (Figure 6.5). Coarse fragments data were used in SOC stock calculations, where available.

Figure 6.4: Locations of points in the validation dataset based on publicly available data

Mass preserving spline functions were applied to estimate the carbon content, bulk density and coarse fragments of a standardized horizon of 0 to 30 cm. Finally, the organic carbon stock was estimated using the GSIF R package. These values were compared with the values in the GSOCmap. The same
dataset was used to compare validation results with 2 other global recent products of SOC, one derived from the Harmonized World Soil Database (HWSD), based on soil type polygon units (Köchy et al., 2015) and a second product derived from the SoilGrids initiative based on machine learning and environmental correlation (Hengl et al., 2017; Poggio et al., 2021). The three SOC maps were resampled from their original resolution to a 1 x 1 km grid and centered on the same spatial extent. This comparison allows to estimate the accuracy of the GSOCmap in relation to other global products and to ground measurements. The results of the validation analysis are shown in table (Table 6.6).

Table 6.6: Comparison of validation criteria between the three SOC products based on international publicly available datasets: FAC2 – fraction of predictions within a factor of two; MB – mean bias; MGE – mean gross error; NMB – normalized mean bias; NMGE – normalized mean gross error; RMSE – root mean squared error; IOA – index of agreement (Willmott et al., 2012).

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<th>MGE</th>
<th>NMB</th>
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<th>RMSE</th>
<th>IOA</th>
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<td>-0.39</td>
<td>35.07</td>
<td>-0.01</td>
<td>0.66</td>
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<td>0.59</td>
<td>0.92</td>
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<td>HWSD</td>
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<td>12.22</td>
<td>44.01</td>
<td>0.23</td>
<td>0.83</td>
<td>75.42</td>
<td>0.37</td>
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The result show that GSOCmap on average has lower error than other global products. Mean gross error (mean absolute error) for GSOCmap is around 35 t/ha, while other global products have error more than 40 t/ha. Root mean squared error is significantly higher than mean absolute error for all products which indicates the presence of a relatively small number of very high errors, most likely associated with organic soils. Global modeling approach of SoilGrids results in the highest mean gross error, while polygon-derived HWSD has higher root mean squared error. However, GSOCmap shows lowest errors in both case which suggests that country-driven approach allows to minimize errors at the global scale. The FAC2 (that takes a value of 1 in a perfect model) indicates the fraction of predictions within a factor of 2 of the observed value. The FAC2 shows a better performance of the GSOCmap. Another important observation is that GSOCmap is almost unbiased (mean bias -0.39 t/ha) while HWSD and especially SoilGrids have significant positive bias (12.21 t/ha and 31.12 t/ha respectively).
To assess the overall quality of the model, Index of Agreement based on Willmott et al. (2012) was applied to all three global products. This index between -1 and +1 with values approaching +1 representing better model performance. GSOCmap showed the highest IOA performance among the three analyzed products with the score 0.5, which indicates that the sum of the error magnitudes is one half of the sum of the observed deviation magnitudes.

These results show that the GSOCmap country-driven approach allows to use much more data locally which helps to minimize errors and ensure better representation of the map. However, since the publicly available datasets mostly cover North and South America and have large gaps in African and Eurasia, the validation dataset may be biased. Therefore, GSP started collecting national datasets that were not used for the development of the GSOCmap, for validation.

For the global comparisons, the analysis based on numerical confusion matrices derived at the pixel level on SAGA GIS (Conrad et al., 2015). A confusion matrix is a specific table layout that allows visualization of the main changes from a reference map (initial state) to another (final state). Thus, it quantifies the absolute difference and the direction of change comparing the GSOCmap with the HWSD, the GSOCmap with SoilGrids and the HWSD with SoilGrids. A map of (positive and negative) changes is derived for each iteration (between the reference and the final state), where values close to 0 represent areas of high agreement between the two compared products.
Figure 6.5: Change vector maps. Derived from a standardized confusion matrix. The map in A shows the changes from GSOCmap to the HWSD, B from the GSOCmap to SoilGrids and C from HWSD to SoilGrids.
It was found that there is a larger agreement between the GSOCmap and HWSD than between the GSOCmap and SoilGrids (Figure 6.6A). While positive and negative changes from the GSOCmap to the HWSD are irregularly distributed, the changes from the GSOCmap to the SoilGrids products tend to be positive, suggesting a major carbon pool predicted by the machine learning approach (Figure 6.6B). A similar pattern was found by analyzing the changes from HWSD to SoilGrids map (Figure 6.6C). These results are useful to identify and quantify differences among products that can be used to inform the development of future versions of country-specific and global SOC mapping efforts.

6.2.2 Uncertainty analysis

Uncertainty analysis aims at quantifying possible deviations of SOC stock estimation on the maps from the real values. SOC map uncertainties come from the soil sampling, measurements of soil properties, and mapping techniques. Although the GSP Secretariat asked the countries to provide information about the uncertainty of their contributed maps, not many countries were able to provide it. Besides, the layers contributed from the countries which could deliver, were generated using different and not comparable methodologies. The different methodologies used included: confidence intervals for the SOC values; standard deviation from regression kriging; standard deviation from an ensemble of different DSM models, and uncertainties as percentage based on expert knowledge. Therefore, a global approach for estimating uncertainties was required.

The uncertainty of the map was estimated by spatial comparison with all available SOC data. For this purpose, several available global, regional and national soil databases were merged, including WoSIS soil profile database (Batjes et al., 2017), LUCAS Soil Database (Toth et al., 2013), Soil Information System for Latin American and the Caribbean (SISLAC) (GSP, 2013), Northern Circumpolar Soil Carbon Database (Hugelius et al., 2013), as well as national datasets provided by participating countries. This database of 276 028 points was used to calculate the residuals of the maps. The residuals were estimated as the difference between the measured and predicted values and expressed in percent of the predicted values by the GSOCmap. The current map presented in Figure 6.7 is the result of the interpolation using ordinary kriging of the residuals. The map shows standard deviations in tonnes/ha.
The current assessment shows highest uncertainty values in the tropical desert and arctic desert areas, due to insufficient number of soil samples from these regions. The difference in uncertainties between the countries in non-desert areas is mainly associated with the density of soil sampling and with the choice of mapping techniques. Based on the map, the uncertainty of global SOC pool value is estimated as +/-144 Pg or around 20 percent.

The uncertainty layers provided by 22 countries (Argentina, Australia, Austria, Belgium, Brazil, Canada, Colombia, Denmark, Ecuador, France, Germany, Hungary, India, Indonesia, Italy, Mexico, Netherlands, Nicaragua, Panama, Russia, Venezuela, Viet Nam) can be requested from the data listed providers in Appendix D.

As part of the envisioned future updates, which will make up the GSOCmap v2.0, a harmonized approach will be implemented to support countries in producing the mandatory uncertainty layers of their national SOC stock maps.

6.3 GSOCmap web services

The GSOCmap Web Services portal is operational with basic functionality while GLOSIS portal is under development (Figure 6.7). The map is available online with functionality allowing to view, query and download the data. It provides in-
formation about data sources acknowledging all organizations which contributed to the map (Figure 6.8).

Figure 6.7: Accessing the GSOCmap on the web
Figure 6.8: GSOCmap web services architecture
Chapter 7

Conclusions and the way forward

The GSOCmap is a product of global efforts made to bring together the existing knowledge about soil organic carbon from all over the world. The map is currently based on more than 1 million profiles, most of the area is covered by original maps produced by the countries. This ensures that the GSOCmap is a global product which is consistent with the national soil knowledge and gives the best available estimation of SOC stocks at the country level. The known issues are the differences at the borders between certain countries and overestimation of SOC stocks for the countries where external datasets were used for gap-filling. These issues will be gradually addressed as more data is collected by countries which will allow to improve national maps and replace gap-filling with original data. A harmonized approach will be implemented to guarantee and support the production of accompanying and mandatory uncertainty estimations of the national SOC stock maps as part of the upcoming GSOCmap 2.0.

The GSOCmap is to be continuously improved as the countries gather more data to improve their maps. The versioning system is being implemented which implies publishing the latest version of the map and keeping all previous versions available upon request.
Versioning system

The GSP uses semantic versioning at certain level so that there is a standard pattern to data releases. Semantic versioning is widely used in the software development world and helps developers having a standardized way of versioning software releases. It follows the format of MAJOR.MINOR.PATCH. The product released on World Soil Day 2017, (5 December) as V1.0.0 and was soon updated to V1.2.0 with minor updates. In June 2019 the map was updated to V1.5.0 with new and updated national contributions, as well as improved gap-filling. The current update to v1.6 presents a further improvement and update of the GSOCmap regarding national submissions as well as gap-filling and external datasets. Change-log is also to be released along with the data with each public release. The current changelog is presented in Annex 10. The future releases will be using the following logic:

Major Major version will be incremented with substantial updates.

Minor Minor version will be incremented with new country submissions, replacements

Patch Patch version will be incremented with error fixes (i.e. removing outliers, fixing calculation errors, etc.)
References


**Global Soil Partnership** 2013. *Sistema de Información de Suelos de Latinoamérica (SISLAC)*. Rome, FAO.


Annex A: Metadata questionnaire

A1: Source data

- Total number of soil profiles/sampling locations;
- Type of sampling (profiles/augers/topsoil);
- Number of locations for each sampling method;
- Sampling Period (e.g. 1980–2007);
- Georeferencing (GPS coordinates/Location names);
- Depth of sampling;
- Sampling design (e.g. transect, catena, land use etc.)

A2: Analysis methods

- Methods of Soil Organic Carbon analysis;
- Methods of Bulk Density analysis (measured/estimated)
  - Details about the sampling;
  - Pedotransfer functions, default values, citations;
- External data-sets (HWSD, SoilGrids.org);
- Methods of Coarse Fragments (measured/estimated/NA)
  - Coarse fragments unit (e.g. % volume / % weight)
- Peat (sampling and description method);

A3: Mapping

- mapping method (DSM / Conventional upscaling)
  - The method(s) used (e.g. Multiple linear regression, Regression-Kriging, Random Forest...);
- Map quality measures (Digital Soil Mapping)
  - Mean error (ME), Mean absolute error, root mean squared error, amount of variance explained;
- Units (tonnes/ha, kg/m2);
- Resampling Method (if used)

A4: Contact details

- Submitter contact details;
- Institute (Data Holder / Handler);
- Citation;
- Update Frequency;
- Comments, Remarks
Annex B: Changelog file of the GSOCmap

GSOCmap:
change log. From 30/05/2019. Most recent changes first / on top.
-----------------------------------------------------------------
VERSION v1.6.0

New submissions: KOR, GEO

Updated national maps: URY, TUR, MKD, LAO, VNM

Updated gap-filling: GTM, BLZ, HND (regional DSM); PRK, TWN, DZA, TUN, LBY, EGY, ISR, MRT, MLI, BFA, NER, TCD, ERI (regional DSM +
global CLM5)

Updated external datasets (replaced Soilgrids with a new version):
MYS, BGD, PNG, CCK, CXR, PLW, SP-, PIS, ABW, AIA, ATG, BES, BLM,
BMU, BRB, CUW, CYM, DMA, GRD, KNA, LCA, MAF, MSR, MTQ, SXM, TCA,
VCT, VGB, ATF, COM, HMD, IOT, MUS, MYT, REU, SYC, COK, FJI, FSM,
KIR, MHL, NCL, NFK, NIU, NRU, PCN, PYF, SLB, TKL, TON, UMI, VUT,
WLF, WSM, XCL, STP, CPV, BVT, SGS, SHN, SPM, GLP, SRB, XKO, MNE,
HRV, ALB

VERSION 1.5.0

* New Country Submissions: AFG, CMR, GMB, MDG
* Joint Effort: BIH, COD, CZE, IRN, PSE
* Improved Country Submissions: ARG, CHL, CUB, DEU, GHA, KHM
* Improved Gap-filling: AGO, BEN, BFA, BWA, CAF, CIV, GIN, GNB, LBR, NAM, SLE, SSD, TGO, ZMB, ZWE, BDI, COG, GAB, GNQ, RWA, UGA
* Improved bulk density estimation for gap-filling maps in Sub-Saharan Africa, using Random Forest prediction
* Major inland water surfaces have been masked out from the map.
* Corrections made in the metadata and list of contributors

**VERSION 1.2.0**

* Country Submission: CHL, COL

**VERSION 1.1.0 -> (Public)**

* Improved Maps: CMR, KHM
* Country Submission: RWA

**VERSION 0.14.2 -> VERSION 1.0.0 (Public)**

* Major inland water Surfaces have been masked out from the map.

**VERSION 0.14**

* New Submissions: DOM, HTI
* FRA has been added to the map (Official Submission)
* Improved maps for ALB, BIH, VRI, CXR, FSM, HRV, MNP, NFK, PLW, SGP, SPM

**VERSION 0.13b**

* FRA has been added to the map (GSP gap Filling).

**VERSION 0.13a**

* Improved maps submitted by ECU, URU, PER
* FRA has been removed from the map "official request"
VERSION 0.12.1

* Corrected map submitted by DEU
* Improved maps for KAZ, UZB, TKM, TJK,

VERSION 0.12

* New country submissions: JOR, SVN
* Improved map of BRA submitted by the country
* Improved maps for KAZ, UZB, TKM, TJK, AFG and PAK using data provided by KAZ and UZB + WOSIS
* Improved GSP gapfilling maps for SVK, DEU and small EU countries: AND, CYP, FRO, GGY, GIB, IMN, JEY, LIE, MCO, VAT, XAD, XNC

VERSION 0.11.1

* New country submission: SDN
* Joint effort: improved map IND

VERSION 0.11

* Joint effort: IND, LAO
* Improved map MAR

VERSION 0.10

* Improved the procedure for filling the NA values between the country borders:
  a 5km buffer along the boarders was used for gap-filling,
  excluding water bodies and coastlines;
  no inland water bodies or urban areas were gap-filled.

VERSION 0.9.1

* Joint effort: SYR
* Improved maps of ETH, ARM submitted by the countries

VERSION 0.9
* SWE Improved
* Gapfilling using LUCAS Soil (GSP): SVK, SVN, ISL and small EU countries: AND, CYP, FRO, GGY, GIB, IMN, JEV, LIE, MCO, VAT, XAD
* Gapfilling GSP for Caribbean (BHS) and GUY, GUF
* Joint Effort: HTI, JAM
* New Submission: DNK, SWZ
* Updated Map: MOZ
* Gapfilling (SoilGrids): Small islands
* Removed No Data zones at borderlines (GDAL, gdal_fillnodata.py, This algorithm will interpolate values for all designated nodata pixels. For each pixel a four direction conic search is done to find values to interpolate from (using inverse distance weighting).
* Changed SoilGrids Source Data (1 km to 250 m)
* Removed Outliers (USA, BRA, DNK)
* Applied global mask

VERSION 0.8

* new corrected map from PRY
* new version of MOZ map submitted by the country
* updated model for MLI
* improved estimation of 0-30 stocks for ESP, IRL, FRA, GRC, BGR, ROU, LTU, LVA, POL, CZE, EST

VERSION 0.7

* Improved bulk density estimation: CHN, BEN, BFA, CIV, GHA, GIN, GNB, LBR, MLI, NGA, SEN, SLE, TGO, BDI, CAF, COD, RWA, SSD, UGA, ZMB, ZWE

VERSION 0.5

* FIN and TZA replaced with the country data
* New Data: CHE, MKD, MLT
* Calculation errors fixed: CUB, IDN, MOZ, MWI
* Improved Model: ESP, IRL, FRA, GRC, BGR, ROU, LTU, LVA, POL, CZE, EST
* Gap Filling (SoilGrids): BGD, LAO, KHM, KOR, PRK, HND, GTM, JAM, HTI, BHS

VERSION 0.4

* Reduced size (VERSION 0.3 exported as Version 0.4 in R (raster pckg))

VERSION 0.3

* Removed reported outliers (above 2000) and minus values

VERSION 0.1

* First map combining the following 0.1 maps:

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Annex B: Changelog

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</tr>
<tr>
<td>95</td>
<td>“pred/own/IDN_BALI_STOCK.tif”</td>
<td>“pred/own/IDN_BALI_STOCK.tif”</td>
</tr>
<tr>
<td>97</td>
<td>“pred/own/IDN_GORONTALO_STOCK.tif”</td>
<td>“pred/own/IDN_GORONTALO_STOCK.tif”</td>
</tr>
<tr>
<td>99</td>
<td>“pred/own/IDN_JATOM_STOCK.tif”</td>
<td>“pred/own/IDN_JATOM_STOCK.tif”</td>
</tr>
<tr>
<td>101</td>
<td>“pred/own/IDN_KALBAR_STOCK.tif”</td>
<td>“pred/own/IDN_KALBAR_STOCK.tif”</td>
</tr>
<tr>
<td>103</td>
<td>“pred/own/IDN_KALTENG_STOCK.tif”</td>
<td>“pred/own/IDN_KALTENG_STOCK.tif”</td>
</tr>
</tbody>
</table>
"pred/own/IDN_ MALUKU_STOCK.tif" "pred/own/IDN_ MALUKU_UTARA_STOCK.tif"
"pred/own/IDN_NTB_ LOMBOK_STOCK.tif" "pred/own/IDN_NTB_ SUMBAWA_STOCK.tif"
"pred/own/IDN_NTT_ FLORES_STOCK.tif" "pred/own/IDN_NTT_ SUMBA_STOCK.tif"
"pred/own/IDN_NTTP_ TIMOR_BARAT_STOCK.tif" "pred/own/IDN_ PAPUA_BARAT_STOCK.tif"
"pred/own/IDN_ PAPUA_STOCK.tif" "pred/own/IDN_ SULBAR_STOCK.tif"
"pred/own/IDN_ SULSEL_STOCK.tif" "pred/own/IDN_ SULTENG_STOCK.tif"
"pred/own/IDN_ SULUT_STOCK.tif" "pred/own/IDN_ SUMATERA_SOC.tif"
"pred/own/IND.tif" "pred/own/IRQ.tif"
"pred/own/ITA.tif" "pred/own/JOR.tif"
"pred/own/JPN.tif" "pred/own/KAZ.tif"
"pred/own/KEN.tif" "pred/own/LBN.tif"
"pred/own/LKA.tif" "pred/own/LSO.tif"
"pred/own/LUX.tif" "pred/own/MAR.tif"
"pred/own/MDA.tif" "pred/own/MEX.tif"
"pred/own/MNG.tif" "pred/own/MOZ.tif"
"pred/own/MWI.tif" "pred/own/NIC.tif"
"pred/own/NLD.tif" "pred/own/NPL.tif"
"pred/own/NZL.tif" "pred/own/PAN.tif"
"pred/own/PER.tif" "pred/own/PHL.tif"
"pred/own/PRY.tif" "pred/own/RUS.tif"
"pred/own/SEN.tif" "pred/own/SLV.tif"
"pred/own/SWE.tif" "pred/own/THA.tif"
"pred/own/TUR.tif" "pred/own/UKR.tif"
"pred/own/URY.tif" "pred/own/USA_ak.tif"
"pred/own/USA_as.tif" "pred/own/USA_conus.tif"
"pred/own/USA_hi.tif" "pred/own/USA_pac_basin.tif"
"pred/own/USA_prvi.tif" "pred/own/UZB.tif"
"pred/own/VEN.tif" "pred/own/VNM.tif"
Annex C: Example scripts used in GSP gapfilling

The scripts used for the different maps prepared by the GSP Secretariat are based in the ones presented in the SOC Mapping Cookbook (Yigini et al., 2018).

C1: Data preparation for soil profiles

```r
dat <- read.csv(file = "data/horizons.csv")
# Explore the data
str(dat)
summary(dat)
dat_sites <- read.csv(file = "data/site-level.csv")
# Explore the data
str(dat_sites)
# summary of column CRF (Coarse Fragments) in the example data base
summary(dat$CRF)
# Convert NA’s to 0
dat$CRF[is.na(dat$CRF)] <- 0
hist(dat$CRF)
# Creating a function in R to estimate
# BLD using the SOC SOC is the soil
# organic carbon content in n%
estimateBD <- function(SOC, method = "Saini_1996") {
```
OM <- SOC * 1.724
if (method == "Saini_1996") {
    BD <- 1.62 - 0.06 * OM
}
if (method == "Drew_1973") {
    BD <- 1/(0.6268 + 0.0361 * OM)
}
if (method == "Jeffrey_1979") {
    BD <- 1.482 - 0.6786 * (log(OM))
}
if (method == "Grigal_1989") {
    BD <- 0.669 + 0.941 * exp(1)^(1 - 0.06 * OM)
}
if (method == "Adams_1973") {
    BD <- 100/(OM/0.244 + (100 - OM)/2.65)
}
if (method == "Honeyset_Ratkowsky_1989") {
    BD <- 1/(0.564 + 0.0556 * OM)
}
return(BD)

# summary of BLD (bulk density) in the example data base
summary(dat$BLD)
# See the summary of values produced using the pedo-transfer function with one of the proposed methods.
summary(estimateBD(dat$SOC[is.na(dat$BLD)], method = "Honeyset_Ratkowsky_1989"))
# Fill NA's using the pedotransfer function:
dat$BLD[is.na(dat$BLD)] <- estimateBD(dat$SOC[is.na(dat$BLD)], method = "Grigal_1989")
# explore the results
boxplot(dat$BLD)
# Load aqp package
library(aqp)
# Promote to SoilProfileCollection

The SoilProfileCollection is an object class in R designed to handle soil profiles.

```r
depths(dat) <- ProfID ~ top + bottom
```

# Merge the soil horizons information with the site-level information from dat_sites

```r
site(dat) <- dat_sites
```

# Set spatial coordinates

```r
coordinates(dat) <- ~ X + Y
```

# A summary of our SoilProfileCollection

```r
dat
```

library(GSIF)

## Estimate 0-30 standard horizon using mass preserving splines

```r
try(SOC <- mpspline(dat, "SOC", d = t(c(0, 30))))
try(BLD <- mpspline(dat, "BLD", d = t(c(0, 30))))
try(CRFVOL <- mpspline(dat, "CRF", d = t(c(0, 30))))
```

## Prepare final data frame

```r
dat <- data.frame(id = dat@site$ProfID, Y = dat@sp@coords[, 2], X = dat@sp@coords[, 1], SOC = SOC$var.std[, 1], BLD = BLD$var.std[, 1], CRFVOL = CRFVOL$var.std[, 1])
dat <- dat[complete.cases(dat), ]
```

## Take a look to the results

```r
head(dat)
```

# Estimate Organic Carbon Stock SOC

## must be in g/kg BLD in kg/m3 CRF in percentage

```r
OCSKGM <- OCSKGM(ORCDRC = dat$SOC, BLD = dat$BLD * 1000, CRFVOL = dat$CRFVOL, HSIZE = 30)
```
dat$OCSKGM <- OCSKGM
dat$meaERROR <- attr(OCSKGM, "measurementError")
dat <- dat[dat$OCSKGM > 0, ]
summary(dat)
## We can save our processed data as a
## table
write.csv(dat, "data/dataproc.csv")

C2: Mixing covariates and soil points data

# Load the processed data. This table
# was prepared in the previous chapter.
dat <- read.csv("data/dataproc.csv")
files <- list.files(path = "covs", pattern = "tif$",
                   full.names = TRUE)
covs <- stack(files)
covs <- stack(covs, soilmap.r)
# correct the name for layer 14
names(covs)[14] <- "soilmap"
# mask the covariates with the country
# mask from the data repository
mask <- raster("data/mask.tif")
covs <- mask(x = covs, mask = mask)
plot(covs)
# upgrade points data frame to
# SpatialPointsDataFrame
coordinates(dat) <- ~X + Y
# extract values from covariates to the
# soil points
dat <- extract(x = covs, y = dat, sp = TRUE)
# LCEE10 and soilmap are categorical
# variables
dat@data$LCEE10 <- as.factor(dat@data$LCEE10)
dat@data$soilmap <- as.factor(dat@data$soilmap)
C3: Fitting a RK model to predict the OCS

# load data
dat <- read.csv("data/MKD_RegMatrix.csv")
dat$LCEE10 <- as.factor(dat$LCEE10)
dat$soilmap <- as.factor(dat$soilmap)
# explore the data structure
str(dat)
library(sp)
# Promote to spatialPointsDataFrame
coordinates(dat) <- ~ X + Y
class(dat)
dat@proj4string <- CRS(projargs = "+init=epsg:4326")
dat@proj4string
library(raster)
# list all the itf files in the folder covs/
files <- list.files(path = "covs", pattern = "tif$", full.names = TRUE)
# load all the tif files in one rasterStack object
covs <- stack(files)
# load the vectorial version of the soil map
soilmap <- shapefile("MK_soilmap_simple.shp")
# rasterize using the Symbol layer
soilmap@data$Symbol <- as.factor(soilmap@data$Symbol)
soilmap.r <- rasterize(x = soilmap, y = covs[[1]], ...
field = "Symbol")

# stack the soil map and the other covariates
covs <- stack(covs, soilmap.r)

# correct the name for layer 14
names(covs)[14] <- "soilmap"

# print the names of the 14 layers:
names(covs)

datdf <- dat@data
datdf <- datdf[, c("OCSKGM", names(covs))]

## Fit a multiple linear regression model
## between the log transformed values
## of OCS and the top 20 covariates
model.MLR <- lm(log(OCSKGM) ~ ., data = datdf)

## stepwise variable selection
model.MLR.step <- step(model.MLR, direction="both")

## summary and anova of the new model
summary(model.MLR.step)
anova(model.MLR.step)

## graphical diagnosis of the regression analysis
par(mfrow=c(2,2))
plot(model.MLR.step)
par(mfrow=c(1,1))

## collinearity test using variance inflation factors
library(car)
vif(model.MLR.step)

# problematic covariates should have sqrt(VIF) > 2

sqrt(vif(model.MLR.step))

## Removing B07CHE3 from the stepwise model:
model.MLR.step <- update(model.MLR.step, . ~ . - B07CHE3)

# Test the vif again:
sqrt(vif(model.MLR.step))

## summary of the new model using stepwise covariates selection
summary(model.MLR.step)

# outlier test using the Bonferroni test
outlierTest(model.MLR.step)

# Project point data.
dat <- spTransform(dat, CRS("+init=epsg:6204"))
# project covariates to VN-2000 UTM 48N
covs <- projectRaster(covs,
    crs = CRS("+init=epsg:6204"), method='ngb')
covs$LCEE10 <- as.factor(covs$LCEE10)
covs$soilmap <- as.factor(covs$soilmap)

## Promote covariates to spatial grid dataframe.
covs.sp <- as(covs, "SpatialGridDataFrame")
covs.sp$LCEE10 <- as.factor(covs.sp$LCEE10)
covs.sp$soilmap <- as.factor(covs.sp$soilmap)

### RK model
library(automap)
## Run regression kriging prediction.
## This step can take hours...!
OCS.krige <- autoKrige(
    formula = as.formula(model.MLR.step$call$formula),
    input_data = dat,
    new_data = covs.sp,
    verbose = TRUE,
    block = c(1000, 1000))
OCS.krige

## Convert prediction and standard deviation to rasters
## And back-transform the values
RKprediction <- exp(raster(OCS.krige$krige_output[1]))
RKpredsd <- exp(raster(OCS.krige$krige_output[3]))
plot(RKprediction)

## Save results as tif files
writeRaster(RKprediction,
    filename = "results/MKD_OCSKGM_RK.tif")
writeRaster(RKpredsd,
    filename = "results/MKD_OCSKGM_RKpredsd.tif")

# save the model
saveRDS(model.MLR.step, file="results/RKmodel.Rds")
library(reshape)
# Correlation analysis to select covariates
names(dat)
COR <- cor(as.matrix(dat[, 7]), as.matrix(dat[, -c(1:8)]))
COR
x <- subset(melt(COR), value != 1 | value != NA)
x <- x[with(x, order(-abs(x$value))), ]
x[1:25, ]
idx <- as.character(x$X2[1:25])
dat2 <- dat[c("OCSKGM", idx)]
names(dat2)
COVall <- COV
COV <- COV[idx]
plot(COV)
library(randomForest)
# Try different values of mtry and # select the model with the optimal # value
model <- tuneRF(dat[, c(names(COV))], dat$OCSKGM,
  stepFactor = 1.5, doBest = TRUE, improve = 0.5)
# Use the model to predict the SOC in # the covariates space
beginCluster()
start <- Sys.time()
pred <- clusterR(COV, predict, args = list(model))
print(Sys.time() - start)
endCluster()
C5: Fitting a svm model to predict the OCS

```r
# Correlation analysis to select covariates
test <- cor(as.matrix(dat[, 7]), as.matrix(dat[, -c(1:8)]))
test
x <- subset(melt(test), value != 1 | value != NA)
x <- x[with(x, order(-abs(x$value))), ]
x[1:25, ]
idx <- as.character(x$X2[1:25])
dat2 <- dat[c("OCSKGM", idx)]
names(dat2)
COVall <- COV
COV <- COV[idx]
plot(COV)
library(e1071)
library(caret)
# Test different values of epsilon and cost
tuneResult <- tune(svm, OCSKGM ~ ., data = dat[c("OCSKGM", names(COV))], ranges = list(epsilon = seq(0, 1, 0.1), cost = c(0.5, 1, 1.5, 2, 5, 10)))
# Choose the model with the best combination of epsilon and cost
tunedModel <- tuneResult$best.model
# Use the model to predict the SOC in the covariates space
beginCluster()
start <- Sys.time()
pred <- clusterR(COV, predict, args = list(tunedModel))
print(Sys.time() - start)
endCluster()
```
Annex D: GSOCmap submission overview

This sections lists the data specifications, methodological specifications, and contacts for each country.

D1: Afghanistan

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 384
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Estimated
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest in R  
Validation: $R^2=48\%$

Contact Point:

Data holder: Hameedullah Ahmadzai  
Institution: FAO Afghanistan  
Email or website: Hameedullah.Ahmadzai@fao.org

D2: Albania

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information  
Email or website: soilgrids.org  

D3: Algeria

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 16
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D4: Andorra

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 0
Time frame: NA
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: N/A


Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D5: Angola

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 962  
Time frame: before and after 1990  
Soil Organic Carbon method: dry combustion  
Bulk density method: mixed  
Coarse fragments method: No data  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe  
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

D6: Antigua and Barbuda

GSOCmap layer source:

Map source: External (soilgrids.org)
Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D7: Argentina

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 5073
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Citation: under review

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest + QRF
Mapping method details: Random forest + QRF
Validation: ME: -0.48 t/ha; RMSE: 17.23 t/ha, AVE: 0.37

Contact Point:

Data holder: Guillermo Federico Olmedo
Institution: Instituto Nacional de Tecnologia Agropecuaria (INTA)
Email or website: olmedo.guillermo@inta.gob.ar
D8: Armenia

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 40
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: linear spectral unmixing pixel based classification
Validation: N/A

Contact Point:
Data holder: Sahakyan Samvel
Institution: Soil Science, Melioration and Agrochemistry Scientific Center named after H. Petrosyan
Email or website: ssahakyan@yandex.ru

D9: Australia

GSOCmap layer source:
Map source: Country submission
Data specifications:

Number of samples: 5588  
Time frame: after 1990  
Soil Organic Carbon method: mixed  
Bulk density method: mixed  
Coarse fragments method: Measured  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Mixed  
Mapping method details: Combination of decision trees with piecewise regression on environmental variables and geostatistical modelling of residuals.  
Validation: Refer to Viscarra Rossel et al. (2014) for detailed analysis of errors and confidence intervals. The total stock of organic C in the 0–30 cm layer of soil for Australia is 24.97 Gt with 95 percent confidence limits of 19.04 and 31.83 Gt. See maps of the 5 percent and 95 percent confidence limits for geographical variation across the continent. Further information on errors can be provided on request.

Contact Point:

Data holder: Mike Grundy  
Institution: CSIRO Agriculture and Food  
Email or website: mike.grundy@csiro.au

D10: Austria

GSOCmap layer source:

Map source: Country submission
**Data specifications:**

Number of samples: 150511  
Time frame: before and after 1990  
Soil Organic Carbon method: mixed  
Bulk density method: Pedotransfer functions  
Coarse fragments method: Estimated  
Citation: FBVA (Ed.) “Osterreichische Waldboden-Zustandsinventur”. Mitteilungen der Forstlichen Bundesversuchsanstalt 168 (1992).

**Methodological specifications:**

Mapping technique: Conventional upscaling  
Mapping method: Mixed  
Mapping method details: N/A  
Validation: N/A

**Contact Point:**

Data holder: Federal research and training center for forest, natural hazards and landscape Austria  
Institution: Dpt. for forest ecology and soil  
Email or website: michael.englisch@bfw.gv.at

**D11: Azerbaijan**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 430  
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Amin Ismayilov
Institution: Institute of Soil Science and Agrochemistry of ANAS
Email or website: amin_ismayilov@mail.ru; amin.ismayil@gmail.com

D12: Bahamas

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: NA
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: N/A
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: Data extracted from the model for Central America based on WOSIS data
Validation: N/A

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D13: Bahrain

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D14: Bangladesh

GSOCmap layer source:

Map source: External (soilgrids.org)
Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D15: Barbados

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D16: Belarus

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 88
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Annex D: GSOCmap submission overview

Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines
Validation: MaE=45.3 t/ha; RMSE=64 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D17: Belgium

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 2457
Time frame: after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: Measured
Citation: C. Chartin, S. Lettens, P. Verschelde, S. Buyle, K. Oorts, P. Engels,

**Methodological specifications:**

Mapping technique: Digital soil mapping

Mapping method: Mixed

Mapping method details: Agricultural land (Flanders): The following empirical regression model was derived based on a dataset of 352 profiles. $\%\text{SOC} = \text{LandUse} + a.\text{clay} + b.\text{H2Omin} + c.\text{LandUse.Clay} + d.\text{LandUse.H2Omin}$ Based on the Belgian soil map and the VITO land use map (Poelmans, 2014), this regression equation was applied to the entire territory of Flanders. Agricultural land (Wallonia): A Generalized Additive Model (GAM; Wood, 2001) was fitted on 2/3 of the dataset. Spatialized environmental covariates (40m x 40m) were used as inputs on the model to map SOC stocks over croplands and grasslands in Wallonia (Southern Belgium); Forest (Flanders): The average soil carbon stock in the upper 30 cm (Cs, in t C/ha) is computed per texture-drainage class of the Belgian soil map. This value is pasted into the 10x10 m² grid of the land use map.; Forest (Wallonia): A Generalized Additive Model (GAM; Wood, 2001) was fitted on 2/3 of the dataset. Spatialized environmental covariates (40m x 40m) were used as inputs on the model to map SOC stocks over forest in Wallonia (Southern Belgium).

Validation: Agricultural land (Flanders): The uncertainty reported is the model uncertainty on point estimates for each data point, in which the estimated model parameters are simulated 1000 times, under the assumption that they are independent and normally distributed variables, using their model estimation and standard error as distribution parameters. (Goidts, 2009 and Meersmans, 2011); Agricultural land (Wallonia): The external validation (on the remaining 1/3 of the dataset) gave a R² of 0.64 and a RMSE of 16 Mg C / ha. ii/ The computation of the prediction uncertainty accounts for the errors associated to both the estimations of i) SOC stocks and ii) parameters of the spatial model (GAM). Hence, two consecutive stochastic simulations (Monte-Carlo method) were used to produce 10,000 (i.e., 100 x 100) independent spatialized datasets. Based on these 10,000 individuals, mean SOC stocks and standard deviation (SD) were computed for each pixel. (Chartin et al., 2017) Forest (Flanders): The uncer-
tainty of the mean (precision) is based on the margin of error (ME) derived from half the 95% confidence interval (CI95%). CI95% are estimated based on bias corrected and accelerated (BCa) percentiles at 2.5 and 97.5% determined by bootstrapping (B = 5000 resamples). Forest (Wallonia): The external validation (on the remaining 1/3 of the dataset) gave a R2 of 0.41, a mean error of 0.3 Mg C /ha, a MAE of 16 Mg C /ha and a RMSE of 18.2 Mg C /ha. ii/ The computation of the prediction uncertainty (standard deviation, SD) accounts only for the errors associated to the estimation of the parameters of the spatial model (GAM). The mgcv package in R provides a Bayesian approach to compute standard errors for the predictions (Wood, 2001).

Contact Point:

Data holder: Vlaamse overheid and Service Public de Wallonie
Institution: Data Holders: Vlaamse overheid and Service Public de Wallonie; Data Handlers: 1) Georges Lemaitre Centre for Earth and Climate Research, Earth and Life Institute, Universite Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium 2) Environment and Climate unit, Research Institute for Nature and Forest, 1070 Brussels, Belgium 3) Vlaams Planbureau voor Omgeving, Departement Omgeving, Vlaamse overheid, 1000 Brussel, Belgium 4) Service Public de Wallonie, Direction Generale de l Agriculture, des Ressources Naturelles et de l Environnement (DGO3), 5100 Namur, Belgium
Email or website: Flanders: katrien.oorts@vlaanderen.be; Wallonia: patrick.engels@spw.wallonie.be

D18: Belize

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 20
Time frame: external datasets
Soil Organic Carbon method: external datasets
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: external datasets

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: N/A
Validation: R²=0.33; MAE=15.88; RMSE=31.28.

**Contact Point:**

Data holder: Global Soil Partnership
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

**D19: Benin**

**GSOCmap layer source:**

Map source: GSP gap-filling
Data specifications:

Number of samples: 714
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D20: Bhutan

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 993
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: Regression tree using cubist and R Kriging using Vesper
Validation: ME 0.5; RMSE 16.3; R2 0.63

Contact Point:

Data holder: Tsheten Dorji and Dr Tshering Dorji
Institution: National Soil Services Centre, Department of Agriculture, Ministry of Agriculture and Forests
Email or website: tshetendorji08@gmail.com and tsericdoji@gmail.com

D21: Bolivia (Plurinational State of)

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 4788
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: R² = 0.287

**Contact Point:**

Data holder: Hernan Figueredo Ticona
Institution: Viceministerio de Tierras
Email or website: hernan.figueroedo@yahoo.com

**D22: Bosnia and Herzegovina**

**GSOCmap layer source:**

Map source: Joint effort with GSP

**Data specifications:**

Number of samples: 1715
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Measured
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: MAE=15.2 t/ha; RMSE=17.8 t/ha;

Contact Point:

Data holder: Prof. dr. Hamid Custovic
Institution: University of Sarajevo
Email or website: custovic.hamid@gmail.com

D23: Botswana

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 839
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D24: Brazil

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 6998
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: Ensemble model combining nine methods (stepwise multiple linear regression, elastic net, principal components regression, partial
least squares regression, multivariate adaptive regression splines, cubist, regression tree, random forest and extreme gradient boosting)
Validation: Training: ME = 1.55 t/ha, RMSE = 21.93 t/ha; Validation: ME = 5.82 t/ha, RMSE = 54.05 t/ha

Contact Point:
Data holder: Gustavo M. Vasques
Institution: Embrapa Solos
Email or website: gustavo.vasques@embrapa.br

D25: Brunei Darussalam

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D26: Bulgaria

GSOCmap layer source:
Map source: GSP gap-filling
Data specifications:

Number of samples: 664  
Time frame: after 1990 
Soil Organic Carbon method: dry combustion 
Bulk density method: Pedotransfer functions 
Coarse fragments method: Measured 

Methodological specifications:

Mapping technique: Digital soil mapping 
Mapping method: Support vector machines 
Mapping method details: Support vector machine model for EU based on LUCAS data 
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership 
Institution: European Soil Data Centre (ESDAC) 
Email or website: esdac@jrc.ec.europa.eu

D27: Burkina Faso

GSOCmap layer source: 
Map source: GSP gap-filling
Data specifications:

Number of samples: 532
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D28: Burundi

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 34
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D29: Cambodia

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 671
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Regression Kriging
Validation: N/A

Contact Point:

Data holder: Dr. Koy Ra
Institution: DALRM, General Directorate of Agriculture
Email or website: koyra2010@yahoo.com

D30: Cameroon

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 1250
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: N/A

Contact Point:

Data holder: Francis B. T. Silatsa and Martin Yemefack
Institution: University of Dschang, Department of Soil Science; International Institute of Tropical Agriculture (IITA), Yaounde
Email or website: silatsat@yahoo.fr; myemefack@yahoo.fr

D31: Canada

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 48017
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: ensemble map from 11 contributions using conventional upscaling, RF, and other algorithms
Validation: We provide a sd based on the variation between overlapping contributions. Error rates for the individual contributions varied from none (polygon averages), low reliability for some maps (10% concordance), and some had better results (30% or higher). Final map reliability estimates await the development of a national validation dataset (in progress).

Contact Point:

Data holder: Bert Vandenbygaart
Institution: Agriculture and Agri-Food Canada
Email or website: bert.vandenbygaart@agr.gc.ca

D32: Cape Verde

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D33: Central African Republic
**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 83  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe  
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

**D34: Chad**
**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 5  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen  
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

**D35: Chile**
**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

- Number of samples: 3258
- Time frame: after 1990
- Soil Organic Carbon method: dry combustion
- Bulk density method: Pedotransfer functions
- Coarse fragments method: No data
- Citation: N/A

**Methodological specifications:**

- Mapping technique: Digital soil mapping
- Mapping method: Random forest
- Mapping method details: Random forest
- Validation: $R^2=0.34$

**Contact Point:**

Data holder: Rodrigo Osorio Hermosilla
Institution: Servicio Agricola y Ganadero, Departamento De Suelos
Email or website: rodrigo.osorio@sag.gob.cl

**D36: China**

**GSOCmap layer source:**

Map source: GSP gap-filling
Data specifications:

Number of samples: 1487  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: No data  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines  
Validation: MAE=32.3 t/ha; RMSE=49.2 t/ha

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

D37: Colombia

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 4329  
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Citation: NA

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Regression-kriging spatial interpolation technique that combines a regression of the dependent variable (target variable) over the predictors (i.e., the environmental covariates) with kriging of the prediction residuals.
Validation: ME: 0.0006705, MAE: 0.5582, RMSE: 0.7416, R2 : 0.5843

**Contact Point:**

Data holder: German Dario Alvarez Lucero
Institution: Instituto Geografico Agustin Codazzi
Email or website: german.alvarez@igac.gov.co

**D38: Comoros**

**GSOCmap layer source:**

Map source: External (soilgrids.org)

**Details:**

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
D39: Congo

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 68
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D40: Cook Islands

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D41: Costa Rica

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 1518
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: No data
Citation: NA

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: MAE = 28.8 t/ha, RMSE=34.9 t/ha, R2=0.265
Contact Point:

Data holder: Alban Rosales Ibarra/Bryan Aleman Montes
Institution: Instituto Nacional de Innovacion de Transferencia en Tecnologia (INTA); Centro de investigaciones Agronomicas, Universidad de Costa Rica
Email or website: arosaarosales@inta.go.cr/bryan.aleman@ucr.ac.cr

D42: Côte d’Ivoire

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 250
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.
Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D43: Croatia

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D44: Cuba

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 30886
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: ME=-5 t/ha; MAE=16.44 t/ha; RMSE=23.74 t/ha; AVE=0.37

Contact Point:

Data holder: Dr. Luis A. Gomez Jorrin (General Director), Dr. Luis B. Rivero Ramos (Project Leader), Roberto Morales
Institution: Instituto de Suelos, Ministerio de Agricultura
Email or website: director@isuelos.co.cu; roberto.morales@isuelos.cu

D45: Cyprus

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 90
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machine model for EU based on LU-CAS data  
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: European Soil Data Centre (ESDAC)  
Email or website: esdac@jrc.ec.europa.eu

**D46: Czech Republic**

**GSOCmap layer source:**

Map source: Joint effort with GSP

**Data specifications:**

Number of samples: 4169  
Time frame: before and after 1990  
Soil Organic Carbon method: dry combustion  
Bulk density method: Measured  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest  
Validation: MAE=13.3 t/ha; RMSE=14.8 t/ha; R2=0.29
Contact Point:

Data holder: Josef Kozak
Institution: Czech University of Life Sciences Prague
Email or website: kozak@af.czu.cz

D47: Democratic People’s Republic of Korea

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D48: Democratic Republic of the Congo

GSOCmap layer source:
Map source: Joint effort with GSP

Data specifications:
Number of samples: 773
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:

Data holder: Eric Lutete Landu ; Yves-Dady Botula Manyala
Institution: Observatoire Satellital des Forets d Afrique Central (OSFAC) /Universite de Kinshasa (Unikin)
Email or website: ericlutete@gmail.com ; ydbotula@yahoo.fr

D49: Denmark

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 46850
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: No data
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Regression kriging
Validation: For the 0-5 cm layer, the mean error was 1.1 g/kg

Contact Point:

Data holder: Mogens H Greve, Mette B Greve
Institution: Agroecology, Aarhus University
Email or website: mogensh.greve@agro.au.dk

D50: Djibouti

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen. Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

**D51: Dominica**

**GSOCmap layer source:**  
Map source: External (soilgrids.org)

**Details:**  
Institution: ISRIC World Soil Information  
Email or website: soilgrids.org  

**D52: Dominican Republic**

**GSOCmap layer source:**  
Map source: Joint effort with GSP
Data specifications:

Number of samples: 120
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Rafael Antonio Rivera
Institution: Ministerio De Medio Ambiente y Recursos Naturales
Email or website: rafantoniorive@gmail.com

D53: Ecuador

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 12861
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: NA

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: R Kriging
Validation: ME: 0.0016; MAE:0.396; RMSE: 0.534; R2: 0.628

Contact Point:

Data holder: Veronica Loayza, Wilmer Jimenez
Institution: Ministerio de Agricultura y Ganaderia del Ecuador
Email or website: veronica_loayza@yahoo.es/wjimenez@mag.gob.ec/nloayza@mag.gob.ec

D54: Egypt

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 22
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: Measured/Estimated
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D55: El Salvador

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 866
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Sol Munoz/ Rene Arevalo
Institution: Ministerio de Medio Ambiente y Recursos Naturales (MARN)/Centro Nacional de Tecnologia Agropecuaria y Forestal (CENTA)
Email or website: smunoz@marn.gob.sv / rene.arevalo@centa.gob.sv

D56: Equatorial Guinea

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally
available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D57: Eritrea

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon,
Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D58: Estonia

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 220
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LU-CAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D59: Eswatini

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 91
Time frame: after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest regression
Validation: RMSE 14.25 t/ha, R2 0.76
Contact Point:

Data holder: Dr. Wisdom M. Dlamini  
Institution: Department of Geography, Environmental Science and Planning, University of Eswatini  
Email or website: mwdlamini@gmail.com, wdlamini@uniswa.sz

D60: Ethiopia

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 58957  
Time frame: after 1990  
Soil Organic Carbon method: soil spectroscopy  
Bulk density method: External Datasets (SoilGrids, HWSD)  
Coarse fragments method: No data  
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest  
Validation: ME = 0.04104367, RMSE = 18.7978, and R2 = 0.5431023

Contact Point:

Data holder: Kiflu Gudeta  
Institution: Ministry of Agriculture and Natural Resources  
Email or website: gkiflu@gmail.com
D61: Faroe Islands

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu
D62: Fiji

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D63: Finland

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 2237
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: mixed
Coarse fragments method: Measured
Citation: Biosoil: https://doi.org/10.5194/gmd-9-4169-2016, 2016, Lucas: https://doi.org/10.1016/j.geoderma.2015.07.006, Soil Database: https://doi.org/10.1016/S0166-2481(06)31005-7

Methodological specifications:
Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: Random forest
Validation: N/A

Contact Point:

Data holder: Harri Lilja
Institution: Natural Resources Institute Finland
Email or website: harri.lilja@luke.fi

D64: France

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 2952
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: Cubist
Validation: N/A
Contact Point:

Data holder: Manuel Martin  
Institution: Institut National de la Recherche Agronomique (INRA)  
Email or website: manuel.martin@inra.fr

D65: Gabon

GSOCmap layer source:  
Map source: GSP gap-filling

Data specifications:

Number of samples: 46  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: Measured/Estimated  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda  
Validation: MAE=16 t/ha; RMSE=19.1 t/ha
Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D66: Gambia

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 24
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: Measured
Citation: NA

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: N/A

Contact Point:
Data holder: Abdou Rahman Jobe
Institution: Soil and Water Management Services Unit, Ministry of Agriculture
Email or website: armjobe@yahoo.com; samatehala@yahoo.co.uk
D67: Georgia

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 0
Time frame: external datasets
Soil Organic Carbon method: external datasets
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: external datasets
Citation: N/A

Methodological specifications:

Mapping technique: external datasets
Mapping method: external datasets
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Global Soil Partnership
Institution: N/A
Email or website: N/A

D68: Germany

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 4863
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Erik Gruneberg, Nicole Wellbrock
Institution: Thunen-Institute of Forests Ecosystems, Thunen-Institutes of Climate-Smart Agriculture
Email or website: erik.grueneberg@thuenen.de, nicole.wellbrock@thuenen.de

D69: Ghana

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 751
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: ME=-2.5 t/ha; MAE=12 t/ha, RMSE =15 t/ha; AVE = 0.18

Contact Point:

Data holder: Stephen Owusu
Institution: CSIR-Soil Research Institute, Kwadaso-Kumasi, Ghana.
Email or website: s.owusu@csir-soilresearch.org ; stephenowusu41@yahoo.com

D70: Greece

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 491
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

**Contact Point:**

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

**D71: Grenada**

**GSOCmap layer source:**

Map source: External (soilgrids.org)

**Details:**

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
D72: Guatemala

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 15
Time frame: external datasets
Soil Organic Carbon method: external datasets
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: external datasets

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: N/A
Validation: R2=0.33; MAE=15.88; RMSE=31.28.

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D73: Guinea**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

- Number of samples: 61
- Time frame: before 1990
- Soil Organic Carbon method: wet oxidation
- Bulk density method: mixed
- Coarse fragments method: Measured/Estimated

**Methodological specifications:**

- Mapping technique: Digital soil mapping
- Mapping method: Random forest
- Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
- Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

**Contact Point:**

- Data holder: Global Soil Partnership
- Institution: Global Soil Partnership

D74: Guinea-Bissau

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 17
Time frame: before 1990
Soil Organic Carbon method: N/A
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D75: Guyana**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 43  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: ensemble of different SVM models based on 238 points from the region  
Validation: N/A

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  
**D76: Haiti**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 135
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: Bayesian Regression where the response variable is observational data from Haiti and the explanatory
Validation: N/A

**Contact Point:**

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D77: Honduras**
GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:

Number of samples: 7
Time frame: external datasets
Soil Organic Carbon method: external datasets
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: external datasets

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: N/A
Validation: R2=0.33; MAE=15.88; RMSE=31.28.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D78: Hungary

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 1236
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Quantile regression forest
Validation: ME= -1.72 t/ha, MAE= 17.08 t/ha, RMSE= 23.18 t/ha

Contact Point:
Data holder: Lazlo Pasztor
Institution: Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences
Email or website: pasztor@rissac.hu

D79: Iceland

GSOCmap layer source:
Map source: GSP gap-filling
Data specifications:

Number of samples: 0  
Time frame: N/A  
Soil Organic Carbon method: N/A  
Bulk density method: N/A  
Coarse fragments method: N/A  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machine model for EU based on LUCAS data  
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership  
Institution: European Soil Data Centre (ESDAC)  
Email or website: esdac@jrc.ec.europa.eu

D80: India

GSOCmap layer source:

Map source: Joint effort with GSP
Data specifications:

Number of samples: 175993
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine
Validation: ME 0.002269 t/ha, RMSE 8.383869 t/ha, R2 0.53

Contact Point:

Data holder: S. K. Singh, A.K. Patra
Institution: National Bureau of Soil Survey and Land Use Planning, Nagpur; Indian Institute of Soil Science, Bhopal
Email or website: skcssri@gmail.com, patraak@gmail.com

D81: Indonesia

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 15750
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: No data
Citation: Sulaeman et al. 2012 Sulaeman et al. 2013, 2014, 2015, 2016

**Methodological specifications:**

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

**Contact Point:**

Data holder: YIYI SULAEMAN
Institution: Indonesian Center for Agricultural Land Resource Research and Development
Email or website: y.sulaeman@gmail.com

**D82: Iran (Islamic Republic of)**

**GSOCmap layer source:**

Map source: Joint effort with GSP

**Data specifications:**

Number of samples: 954
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A
**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest  
Validation: $R^2 = 0.58$, RMSE = 18.5 t/ha

**Contact Point:**

Data holder: Kambiz Bazargan  
Institution: Soil and Water Research Institute (SWRI)  
Email or website: bazargan_k@yahoo.com

**D83: Iraq**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 400  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: External Datasets (SoilGrids, HWSD)  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: N/A  
Validation: N/A
Contact Point:

Data holder: Dr Eman
Institution: Ministry of Agriculture
Email or website: eman_sahib@yahoo.com

D84: Ireland

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 233
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha
Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D85: Israel

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:

Number of samples: 12
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured/Estimated

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha
Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D86: Italy

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 6748
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: mixed
Coarse fragments method: Measured

Citation: SCS map of Italy partnership: structure and contributions Coordinator: Edoardo Costantini CREA Firenze. WG1 Data, metadata and covariates supplying: CREA-Firenze; CREA-Roma; ISPRA (covariates); IPLA, Piemonte; ERSAF, Lombardia; ARPA Veneto; ERSA-FVG, Friuli Venezia-Giulia; Regione Liguria; SGSS, Emilia-Romagna; Consorzio Lamma, Toscana; Regione Marche; Regione Campania; Regione Puglia, Universita di Foggia, Universita Mediterranea di Reggio Calabria, ARSSA, Calabria; Regione Sicilia. WP2 Harmonization of SOC analytical methods and bulk density values and estimation a) SOC methods: ARPA Veneto Universita Mediterranea di Reggio Calabria; Universita di Foggia; CREA-Roma; CNR-ISE, Firenze. b) Bulk density estimation: CNR-Ibimet; Firenze; CREA, Firenze; ARPA Veneto; Consorzio Lamma, Firenze; SGSS, Emilia-Romagna. WP3 Digital soil mapping: Methods: CNR-Ibimet, Firenze; CREA Firenze; CREA Roma. Quality checking: ARPA Veneto; SGSS, Emilia-Romagna. WP4-elaboration and management of data and maps: CREA Firenze; CNR-Ibimet, Firenze. Authors (alphabetical order for institutions and authors) Paolo Giandon, Ialina Vinci (ARPA Veneto); Raffaele Paone (ARSSA, Calabria); Costanza Calzolari, Fabrizio Ungaro (CNR Ibimet); Luigi D Acqui
(CNR ISE); Lorenzo Gardin (Consorzio Lamma, Toscana); Edoardo Costantini, Maria Fantappi, Giovanni L Abate, Sergio Pellegrini, (CREA Firenze); Maria Teresa Dell Abate, Rosario Napoli (CREA Roma); Stefano Barbieri (ERSA-FVG); Stefano Brenna (ERSAF, Lombardia); Fabio Petrella, Paolo Martali (IPLA, Piemonte); Michele Munafi, Fiorenzo Fumanti (ISPRA ); Amedeo D Antonio (Regione Campania); Paola Tarocco, Francesca Staffilani (Regione Emilia-Romagna SGSS); Stefano Pini (Regione Liguria), Mauro Tiberi (Regione Marche); Luigi Scamarcio (Regione Puglia); Fabio Guaitoli (Regione Sicilia); Claudio Zaccone (Universita di Foggia); Adele Muscolo (Universita Mediterranea di Reggio Calabria).

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: Neural Networks and GLM, according to soil region
Validation: Mean Error (ME) of the prediction is 1.688 Mg/ha, MAE 25.57 Mg/ha, Root Mean Squared Error (RMSE) is 36.24 Mg/ha.

Contact Point:

Data holder: Edoardo Costantini
Institution: Research centre for agriculture and environment (CREA)
Email or website: edoardo.costantini@crea.gov.it

D87: Jamaica

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 77
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Quantile Regression Forest
Validation: N/A

**Contact Point:**

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D88: Japan**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 6254
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: Measured
Citation: N/A
Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Cropland: Hiroshi Obara, Forests: Shigehiro Ishizuka
Institution: Cropland: Institute for Agro-Environmental Sciences, NARO,
Forests: Forestry and Forest Products Research Institute
Email or website: Cropland: obara@affrc.go.jp, Forest: ishiz03@ffpri.affrc.go.jp

D89: Jordan

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 1072
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Multiple linear regression, Kriging
Validation: R2 (0.92)
Contact Point:

Data holder: Mahmoud alfraihat
Institution: MOA
Email or website: Mahmoudalfrehat@gmail.com

D90: Kazakhstan

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 502
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: R2 =0.88, RMSE=10.5 t/ha

Contact Point:

Data holder: Maira Kussainova
Institution: Kazakh Research Institute of Soil Science and Agrochemistry
named after U.U. Uspanov
Email or website: madgu@inbox.ru

**D91: Kenya**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 2059  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Other  
Mapping method details: Environmental Correlation  
Validation: RMSE=39.72 t/ha ;AC=0.657806; MAE=28.958 t/ha; SDOV=36.117432; ME=1.09 t/ha Where: RMSE is root mean square error; AC is agreement coefficient; MAE is mean absolute error; SDOV is standard deviation of observed values; ME is mean error.
Contact Point:

Data holder: Peter Kamoni, Matolo Nyamai
Institution: Kenya Agricultural and Livestock Research Organization
Email or website: Peter kamoni(pkamoni@gmail.com) Matolo Nyamai(matolonyamai@gmail.com/nyamai.matolo@kalro.org)

D92: Kiribati

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D93: Kuwait

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D94: Kyrgyzstan**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: $R^2 = 0.88$, RMSE = 10.5 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D95: Lao People’s Democratic Republic

GSOCmap layer source:

Map source: Joint effort with GSP

Data specifications:

Number of samples: 155
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: $R^2=0.34; MAE=13.65; RMSE=21.44.$

Contact Point:

Data holder: Ministry of Agriculture and Forestry of Laos
Institution: Ministry of Agriculture and Forestry of Laos
Email or website: http://www.maf.gov.la/

D96: Latvia

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 349
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LU-CAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D97: Lebanon

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 450
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Other  
Mapping method details: Kriging  
Validation: N/A

**Contact Point:**

Data holder: Talal Darwish  
Institution: Handler Institute: National Council for Scientific Research CNRS Lebanon  
Email or website: tdarwich@cnrs.edu.lb; tlldarwish@gmail.com

**D98: Lesotho**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 74  
Time frame: before 1990  
Soil Organic Carbon method: N/A  
Bulk density method: Measured  
Coarse fragments method: Measured  
Citation: Cauley, P. M., 1986. Benchmark soils of Lesotho: their classification, interpretation, use, and management. Maseru, Lesotho.

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Mixed
Mapping method details: Multiple linear regression, R Kriging, Random forest
Validation: N/A

Contact Point:

Data holder: Koetlisi Koetlisi
Institution: Ministry of Forestry, Range and Soil Conservation
Email or website: koetlisika@email.com and lesis2017@gmail.com

D99: Liberia

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 48
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Citation: Batjes, N. H., Ribeiro, E., van Oostrum, A., Leenaars, J., Hengl, T.,
and Mendes de Jesus, J.: WoSIS: providing standardised soil profile data for the
2045

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya,
Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

**Contact Point:**

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

**D100: Libya**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 14
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

**Methodological specifications:**

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon,
Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D101: Lithuania

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 356
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LU-CAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: European Soil Data Centre (ESDAC)  
Email or website: esdac@jrc.ec.europa.eu

**D102: Luxembourg**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 3492  
Time frame: after 1990  
Soil Organic Carbon method: dry combustion  
Bulk density method: Pedotransfer functions  
Coarse fragments method: Estimated  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Linear Models  
Mapping method details: Generalized Additive Models (covariates: Land use, Elevation, precipitation, temperature, C factor, % Clay (80x80m))  
Validation: For cropland soils: R2 = 0.66, RMSE = 5.5 g C kg-1
Contact Point:

Data holder: Marx Simone
Institution: Administration of agricultural technical services - Soil department
Email or website: simone.marx@asta.etat.lu

D103: Madagascar

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 1193
Time frame: after 1990
Soil Organic Carbon method: mixed
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: $R^2=0.59$; RMSE=25.8 t/ha

Contact Point:

Data holder: Andry Andriamananjara
Institution: Laboratoire des Radioisotopes, University of Antananarivo
Email or website: njaraandry1@gmail.com
D104: Malawi

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 4922
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: No data
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Linear Models
Mapping method details: Multiple linear regression
Validation: N/A

Contact Point:
Data holder: Kefasi Kamoyo/ John Mussa
Institution: Department of Land Resources Conservation, Ministry of Agriculture, Irrigation and Water Development,
Email or website: kamokefa@yahoo.com/ mussajj@gmail.com

D105: Malaysia

GSOCmap layer source:
Map source: External (soilgrids.org)
Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D106: Maldives

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D107: Mali

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 667
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured/Estimated

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D108: Malta

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 19
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured


Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D109: Marshall Islands

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
**D110: Mauritania**

**GSOCmap layer source:**
Map source: GSP gap-filling

**Data specifications:**
- Number of samples: 11
- Time frame: before 1990
- Soil Organic Carbon method: N/A
- Bulk density method: Pedotransfer functions
- Coarse fragments method: Measured/Estimated

**Methodological specifications:**
- Mapping technique: Digital soil mapping
- Mapping method: Support vector machines
- Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
- Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**
- Data holder: Global Soil Partnership
- Institution: Global Soil Partnership
D111: Mauritius

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D112: Mexico

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 36015
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: mixed
Coarse fragments method:Measured
Citation: Soil Organic Carbon Map 2017. Mexico.

Methodological specifications:

Mapping technique: Conventional upscaling, Digital soil mapping
Mapping method: Mixed
Mapping method details: Mixed. Iterative Calibration map and Linear Regression. To spatially represent SOC information we use regionalization models that represent changes in average SOC values as a function of changes in factors of soil formation (or loss); such as gravity (inclination), climate, vegetation, land use, water erosion, deforestation, degradation and recovery. Each logical relationship has both exception rules and quantitative trend graphs for the continuous range of carbon values, which is established from the available cartographic information. Digital soil mapping techniques are also used to build statistical models and spatial predictions of SOC and depth. The ongoing development and the implementation of a national soil spatial inference engine assisted with high performance computing techniques will allow to periodically provide wall-to-wall SOC estimates at relevant scales for natural resources management.

Validation: Four error factors are considered: (1) Disaggregation or level of detail in the available data. (2) Density or number of field observations per study surface. (3) Dispersion or heterogeneity represented by the coefficient of variation (Cv) obtained from the quotient of the standard deviation and the mean of each covariate of organic carbon (relief, geology, climate, vegetation, human management and various soil processes), and (4) Representation or congruence (qualitative evaluation of expert) between the study sites (points) and the carbon magnitude polygons represented. For the estimation of uncertainties follows the good practices suggestions from the IPCC (2003) through the use of the inverse of variance and R2.

Contact Point:

Data holder: Carlos Cruz-Gaistardo
Institution: 1 Instituto Nacional de Estadistica y Geografia. INEGI. omar.cruz@inegi.org.mx 2 Comision Nacional Forestal. CONAFOR. 3 Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias. INIFAP. 4 Red Nacional de Laboratorios para el Analisis, Uso, Conservacion y Manejo del Suelo. REDLABs. 5 Colegio de Postgraduados. COLPOS. 6 Colegio de la Frontera Sur. ECOSUR. 7 Organizacion de las Naciones Unidas para la Agricultura y la Alimentacion. FAO. 8 University of Delaware, UDEL. 9 Programa de las Naciones Unidas para el Desarrollo. PNUD.
Email or website: omar.cruz@inegi.org.mx
D113: Micronesia (Federated States of)

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D114: Monaco

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LU-CAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D115: Mongolia

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 512
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model
Validation: ME= 1.0 t/ha, MAE=22.6 t/ha, RMSE=30.0 t/ha, R2=0.36
Contact Point:

Data holder: Bayarsukh Noov
Institution: Institute of Plant and Agriculture Science
Email or website: bayar67@yahoo.com

D116: Montenegro

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D117: Morocco

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 24000
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured
Citation: N/A
Methodological specifications:

Mapping technique: Conventional upscaling, Digital soil mapping
Mapping method: Mixed
Mapping method details: esoter approach for soil unit and idw for regression
Validation: N/A

Contact Point:

Data holder: Dr Rachid Moussadek
Institution: INRA Morocco
Email or website: rachidmoussadek@yahoo.fr

D118: Mozambique

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 2427
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest Method
Validation: ME=4.4, R2=0.31
**Contact Point:**

Data holder: Orlando Inacio Jalane  
Institution: Mozambique Agrarian Reserch Institute  
Email or website: ojalane@gmail.com

**D119: Myanmar**

**GSOCmap layer source:**

Map source: Joint effort with GSP

**Data specifications:**

Number of samples: 115  
Time frame: after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines  
Validation: N/A

**Contact Point:**

Data holder: N/A  
Institution: Ministry of Agriculture, Livestock and Irrigation (MoALI)  
Email or website: Su Su Win susuwinmyanmar@gmail.com
D120: Namibia

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 56
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D121: Nauru

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D122: Nepal

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 6000
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A
Contact Point:

Data holder: Soil Science Division
Institution: Nepal Agricultural Research Council
Email or website: matobigyan@gmail.com

D123: Netherlands

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 21210
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: R Kriging
Validation: N/A

Contact Point:

Data holder: Dennis Walvoort and Tom Hoogland
Institution: Wageningen University and Research, The Netherlands
Email or website: https://www.wur.nl/en.htm
D124: New Zealand

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 2050
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: Estimated

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Linear Models
Mapping method details: generalized linear model (GLM)
Validation: A test of the measured and predicted soil carbon stocks using the Lenz level 4 environmental classification model (the best of the four developed) indicates a residual standard error of 24.4 t/ha using a robust Gaussian fit of the model residuals.

Contact Point:

Data holder: Stephen McNeill
Institution: Landcare Research
Email or website: mcneills@landcareresearch.co.nz
**D125: Nicaragua**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 4000  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Random forest and Support vector machine  
Validation: N/A

**Contact Point:**

Data holder: Fernando J Mendoza Jara  
Institution: Universidad Nacional Agraria  
Email or website: fmendoza@ci.una.edu.ni

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**D126: Niger**

**GSOCmap layer source:**

Map source: GSP gap-filling
Data specifications:

Number of samples: 478  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: Measured/Estimated  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen  
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

D127: Nigeria

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 5545
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Linear Models
Mapping method details: Multiple linear regression
Validation: RMSE 18.9 t/ha, R2 0.529, ME 9.18 t/ha

Contact Point:

Data holder: Oshadiya Pekun
Institution: Federal department of Agricultural Lands and Climate Change Management Service
Email or website: oshadiyapekun@gmail.com

D128: Niue

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
Citation: Poggio, L., De Sousa, L. M., Batjes, N. H., Heuvelink, G., Kempen,

**D129: North Macedonia**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 4300  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest  
Validation: AVE=0.42; MAE=19.49; RMSE=25.73.

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Dusko Mukaetov  
Email or website: NA
D130: Norway

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 3218
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: ensemble of 6 models: random forest, cubist, kernels, decision trees, principal components and partial least square regression
Validation: N/A

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D131: Oman
**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 9  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: Pedotransfer functions  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen  
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

**D132: Pakistan**
Annex D: GSOCmap submission overview

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 337
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: $R^2 = 0.88$, $RMSE = 10.5$ t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D133: Palau
GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D135: Panama

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 837
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: R Kriging
Validation: N/A
Contact Point:

Data holder: Ivan Ramos
Institution: IDIAP
Email or website: iarz1103@gmail.com

D136: Papua New Guinea

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D137: Paraguay

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 2768
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: ME: 16.6 t/ha; MAE: 33.9 t/ha; RMSE: 31.2 t/ha; R2: 0.1416

Contact Point:

Data holder: Ministry of Agriculture MAG
Institution: Secretary of Environment SEAM
Email or website: no available

D138: Peru

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 1010
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines
Validation: N/A
Contact Point:

Data holder: Honnan Denis Ponte Saldana
Institution: Ministerio de Agricultura y Riego
Email or website: hponte1410@gmail.com, hponte@minagri.gob.pe

D139: Philippines

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 500
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: Kriging
Validation: RMSE = 0.48

Contact Point:

Data holder: Baldwin Morales Pine
Institution: Bureau of Soils and Water Management
Email or website: baldwinmp@gmail.com/rodelcarating@yahoo.com/angelenriquez.bswm@gmail.com
D140: Poland

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 1648
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu
D141: Portugal

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 476
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: $ME = -5.7 \text{ t/ha}; \text{MAE}=32.9 \text{ t/ha}; \text{RMSE}=45.7 \text{ t/ha}$

Contact Point:
Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu
D142: Qatar

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE = 6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D143: Republic of Korea

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 0
Time frame: external datasets
Soil Organic Carbon method: external datasets
Bulk density method: External Datasets (SoilGrids, HWSD)
Coarse fragments method: external datasets
Citation: N/A

Methodological specifications:

Mapping technique: external datasets
Mapping method: external datasets
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Global Soil Partnership
Institution: N/A
Email or website: N/A

D144: Republic of Moldova

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 0
Time frame: before 1990
Soil Organic Carbon method: estimated
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: NA

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Other
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Iurii Rozloga
Institution: Institute of Pedology, Agrochemistry and Soil Protection “N. Dimo”, Moldova
Email or website: iu.rozloga@gmail.com

D145: Romania

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 1384
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D146: Russian Federation

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 150000
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
Citation: Golozubov O.M., Chernova O.V. Using multi-scale old and modern maps combined with current soil monitoring data for online mapping the soil organic carbon stocks // International Conference “Global Soil Map 2017” Moscow, Russia, July 4-6, 2017. Materials of conference. p. 36.

**Methodological specifications:**

Mapping technique: Conventional upscaling, Digital soil mapping
Mapping method: Mixed
Mapping method details: Used both conventional upscaling and DSM. For DSM: regression equations, IWD and kriging, fuzzi sets depending on area of country and sample density
Validation: Under development yet

**Contact Point:**

Data holder: Oleg Golozubov
Institution: Soil science department of M.V.Lomonosov MSU, soil data center; Soil science department of Southern State University; Agrochemical data center “Rostovsky” of the Ministry of agriculture of the Russian Federation; Agrochemical data center “Belgorodsky” of the Ministry of agriculture of the Russian Federation; Severtsov Institute of Ecology and Evolution of the Russian Academy of Sciences; Mytischi filial of Bauman Moscow State Technical University, soil science department; International Institute for Applied Systems Analysis, Ecosystem Services and Management program
Email or website: oleggolozubov@gmail.com

**D147: Rwanda**

**GSOCmap layer source:**

Map source: GSP gap-filling
Data specifications:

Number of samples: 88  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: Measured/Estimated  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda  
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

D148: Saint Kitts and Nevis

GSOCmap layer source:

Map source: External (soilgrids.org)
Annex D: GSOCmap submission overview

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D149: Saint Lucia

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D150: Saint Vincent and the Grenadines

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org
Citation: Poggio, L., De Sousa, L. M., Batjes, N. H., Heuvelink, G., Kempen,

D151: Samoa

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D153: Sao Tome e Principe

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org
**D154: Saudi Arabia**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 0  
Time frame: N/A  
Soil Organic Carbon method: N/A  
Bulk density method: N/A  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen  
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  
**D155: Senegal**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

- Number of samples: 678
- Time frame: after 1990
- Soil Organic Carbon method: wet oxidation
- Bulk density method: External Datasets (SoilGrids, HWSD)
- Coarse fragments method: Estimated
- Citation: N/A

**Methodological specifications:**

- Mapping technique: Digital soil mapping
- Mapping method: Regression Kriging
- Mapping method details: R Kriging
- Validation: MAE 10.2 t/ha, RMSE 18.1 t/ha, R2: 0.67

**Contact Point:**

Data holder: Macoumba Loum
Institution: Institut National de Pedologie
Email or website: macoumbaloum@yahoo.fr

**D156: Serbia**

**GSOCmap layer source:**

Map source: External (soilgrids.org)
Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D157: Seychelles

GSOCmap layer source:
Map source: External (soilgrids.org)

Details:
Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D158: Sierra Leone

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 11
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D159: Singapore

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

**D160: Slovakia**

**GSOCmap layer source:**

Map source: Country submission

**Data specifications:**

Number of samples: 16748
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: N/A

**Methodological specifications:**

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

**Contact Point:**

Data holder: Rastislav Skalsky (agricultural soils); Pavel Pavlenda (forest soils)
Institution: National Agricultural and Food Centre, Soil Science and Conservation Research Institute (agricultural soils); National Forestry Centre, Forestry Research Institute (forest soils)
Email or website: r.skalsky@vupop.sk; pavlenda@nlcsk.org
D161: Slovenia

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 1681
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:
Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:
Data holder: Borut Vrscaj
Institution: Agricultural institute of Slovenia
Email or website: borut.vrscaj@kis.si

D162: Solomon Islands

GSOCmap layer source:
Map source: External (soilgrids.org)
Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D163: Somalia

GSOCmap layer source:

Map source: Joint effort with GSP

Data specifications:

Number of samples: 257
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines
Validation: ME=3.2 t/ha; MAE=10.7 t/ha; RMSE=16.3 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Somalia Water and Land Information Management (SWALIM)
Email or website: swalim@fao.org
D164: South Africa

GSOCmap layer source:

Map source: Joint effort with GSP

Data specifications:

Number of samples: 11257
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines
Validation: ME=0.07 t/ha; MAE=19.3 t/ha; RMSE=27.6 t/ha

Contact Point:

Data holder: Dr. Maila
Institution: Soil, Climate and Water (ARC-SCW)
Email or website: scwinfo@arc.gis.za

D165: South Sudan

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D166: Spain

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 2696
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine model for EU based on LUCAS data
Validation: ME = -5.7 t/ha; MAE=32.9 t/ha; RMSE=45.7 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: European Soil Data Centre (ESDAC)
Email or website: esdac@jrc.ec.europa.eu

D167: Sri Lanka

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 233
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Linear Models
Mapping method details: Multiple linear regression
Validation: N/A

Contact Point:

Data holder: Dr. Ajantha de Silva
Institution: Natural Resources Management Centre, Department of Agriculture
Email or website: ajandes@gmail.com

D168: Sudan

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 1584
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: STATISTICS_MAXIMUM=4.8131771087646 STATISTICS_MEAN=1.1700157773579
STATISTICS_MINIMUM=0.001964766299352 STATISTICS_STDDEV=0.71722792069521

Contact Point:

Data holder: Abdelmagid Ali Elmobarak
Institution: Land and Water Research Centre,
Email or website: melmobarak2012@gmail.com

D169: Suriname

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 178
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data
Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machine
Validation: N/A

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D170: Sweden

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 19097
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: mixed
Coarse fragments method: Measured

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Other
Mapping method details: Multivariate adaptive regression splines (MAR-Splines)
Validation: N/A

**Contact Point:**

Data holder: Johan Stendahl  
Institution: Dep of Soil and Environment, SLU  
Email or website: johan.stendahl@slu.se

**D171: Switzerland**

**GSOCmap layer source:**

Map source: Joint effort with GSP

**Data specifications:**

Number of samples: 1175  
Time frame: after 1990  
Soil Organic Carbon method: dry combustion  
Bulk density method: Measured  
Coarse fragments method: Measured  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Mixed  
Mapping method details: Caret ensemble of Random forest, Cubist, KKNN, Bayesian trees, Partial Least Squares Regression, Principal Components Regression  
Validation: ME=-7.1 t/ha; MAE=23.1 t/ha; RMSE=34.4 t/ha
Contact Point:

Data holder: Fabio Wegmann
Institution: Federal Office for the Environment, Soil and Biotechnology Division
Email or website: fabio.wegmann@bafu.admin.ch

D172: Syrian Arab Republic

GSOCmap layer source:

Map source: Joint effort with GSP

Data specifications:

Number of samples: 1220
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured/Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines
Validation: ME=-0.03 t/ha; MAE=10.1 t/ha; RMSE=14.3 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: General Commission for Scientific Agriculture Research
Email or website: Syrian Arab Republic, Damascus, Al-Hyjazz Square, General Commission for Scientific Agriculture Research
D173: Tajikistan

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 21
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: No data

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: R2 =0.88, RMSE=10.5 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D174: United Republic of Tanzania

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 3215
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured
Citation: Kempen, B. 2016. Development of a soil carbon map for the United Republic of Tanzania. ISRIC, Wageningen.

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: R. Kriging, Random forest
Validation: ME: -0.00, MAE: 12.3, RMSE: 18.0, R2: 0.53

Contact Point:

Data holder: Joseph D. Mbogoni
Institution: Agricultural Research Institute Mlingano
Email or website: jdjmbogoni@gmail.com

D175: Thailand

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 70000
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Suradesh Tiewtrakool
Institution: Land Development Department
Email or website: dgldd@ldd.go.th

D176: Timor-Leste

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
D177: Togo

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

- Number of samples: 9
- Time frame: before and after 1990
- Soil Organic Carbon method: wet oxidation
- Bulk density method: mixed
- Coarse fragments method: No data

**Methodological specifications:**

- Mapping technique: Digital soil mapping
- Mapping method: Random forest
- Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe
- Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

**Contact Point:**

- Data holder: Global Soil Partnership
- Institution: Global Soil Partnership
D178: Tokelau

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D179: Tonga

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D180: Trinidad and Tobago

GSOCmap layer source:

Map source: Joint effort with GSP
**Data specifications:**

Number of samples: 122  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: No data  
Citation: N/A

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Geomatching / Class-matching  
Mapping method details: Support vector machine based on statistical simulation of the position of sampling points  
Validation: N/A

**Contact Point:**

Data holder: Ronald Roopnarine. Gaius Eudoxie  
Institution: University of The West Indies  
Email or website: ronald.roopnarine@sta.uwi.edu

**D181: Tunisia**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 58  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured/Estimated

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D182: Turkey

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 31800
Time frame: after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: Measured
Coarse fragments method: No data
Citation: within the context of “Establishment of National Geospatial Soil Fertility and Soil Information System Project UTF/TUR/057/TUR, in collaboration with FAO

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Multiple Regression Kriging
Validation: AVE=0.51; MAE=13.36; RMSE=20.84.

Contact Point:

Data holder: Dr. Bulent Sonmez, Doc. Dr. Aynur Ozbance
Institution: General Directorate of Agricultural Research And Policies, Soil, Fertilizer and Water Resources Central Research Institute Ankara, TURKEY
Email or website: bulent.sonmez@tarim.gov.tr, aynur.ozbahce@tarim.gov.tr

D183: Turkmenistan

GSOCmap layer source:

Map source: GSP gap-filling

Data specifications:

Number of samples: 0
Time frame: N/A
Soil Organic Carbon method: N/A
Bulk density method: N/A
Coarse fragments method: No data
Citation: Batjes, N. H., Ribeiro, E., van Oostrum, A., Leenaars, J., Hengl, T.,

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: R² = 0.88, RMSE = 10.5 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D184: Tuvalu

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org
D185: Uganda

GSOCmap layer source:
Map source: GSP gap-filling

Data specifications:
Number of samples: 12
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: mixed
Coarse fragments method: Measured/Estimated

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Burundi, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda, Uganda
Validation: MAE=16 t/ha; RMSE=19.1 t/ha

Contact Point:
Data holder: Global Soil Partnership
Institution: Global Soil Partnership
D186: Ukraine

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 3931
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: mixed
Coarse fragments method: No data
Citation: K. Viatkin, Yu. Zalavskyi, O. Bihun, V. Lebed, O. Sherstiuk, I. Plisko, S. Nakisko. Creation of the Ukrainian national soil organic carbon stocks map using digital soil mapping methods // Soil Science and Agrochemistry, Almaty, Kazakhstan, n2 2018, p. 5-17

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Mixed
Mapping method details: Random forest
Validation: For mineral soils: ME=0.1 t/ha, MAE=13.2 t/ha; RMSE=18.2 t/ha, R2=0.56. For peat soils: ME=-1.2 t/ha, MAE=18.7 t/ha, RMSE=24.5 t/ha, R2=0.22.

Contact Point:

Data holder: Sviatoslav Baliuk
Institution: National Scientific Center “Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky” (NSC ISSAR) and contributors
Email or website: pochva@meta.ua
**D187: United Arab Emirates**

**GSOCmap layer source:**

Map source: GSP gap-filling

**Data specifications:**

Number of samples: 0  
Time frame: NA  
Soil Organic Carbon method: N/A  
Bulk density method: N/A  
Coarse fragments method: No data  

**Methodological specifications:**

Mapping technique: Digital soil mapping  
Mapping method: Support vector machines  
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen  
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

**Contact Point:**

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  
D188: United Kingdom of Great Britain and Northern Ireland

GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 17421
Time frame: before and after 1990
Soil Organic Carbon method: mixed
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Caroline Keay
Institution: Cranfield University
Email or website: c.keay@cranfield.ac.uk

D189: United States of America
GSOCmap layer source:

Map source: Country submission

Data specifications:

Number of samples: 10000
Time frame: before and after 1990
Soil Organic Carbon method: dry combustion
Bulk density method: mixed
Coarse fragments method: Estimated
Citation: N/A

Methodological specifications:

Mapping technique: Conventional upscaling
Mapping method: Geomatching / Class-matching
Mapping method details: N/A
Validation: N/A

Contact Point:

Data holder: Micheal Robotham
Institution: Natural Resource Conservation Service
Email or website: michael.robotham@wdc.usda.gov

D190: Uruguay

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 160
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Estimated
Citation: Direccion General de Recursos Naturales-DGRN Ministerio de Ganaderia y Agricultura y Pesca-MGAP - Uruguay 2017

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Regression Kriging
Mapping method details: Multiple linear regression, R Kriging,
Validation: RMSE = 0.4566, MAE= 0.3558, me_mean= -0.0002158, R2=0.5549

Contact Point:

Data holder: Martin Dell Acqua Gonzalo Pereira Pablo Prieto Fernando Fontes Fabian Davila
Institution: Direccion General de Recursos Naturales
Email or website: mdellacqua@mgap.gub.uy mdavila@mgap.gub.uy ffontes@mgap.gub.uy pprieto@mgap.gub.uy gpereira@mgap.gub.uy

D191: Uzbekistan

GSOCmap layer source:

Map source: Country submission
Data specifications:

Number of samples: 4969
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: No data
Citation: N/A

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest model based on the ensemble globally available data from Afghanistan, Pakistan, Turkmenistan, Tajikistan, Kyrgyzstan and the original data provided by Kazakhstan and Uzbekistan.
Validation: $R^2 = 0.88$, RMSE=10.5 t/ha

Contact Point:

Data holder: Bakhodir Ruziboev
Institution: UZGIP Design and Research Institute
Email or website: uzgip_tas@umail.uz, uzgip@bk.ru

D192: Vanuatu

GSOCmap layer source:

Map source: External (soilgrids.org)

Details:

Institution: ISRIC World Soil Information
Email or website: soilgrids.org

D193: Venezuela (Bolivarian Republic of)

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 310
Time frame: before and after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: No data
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: RMSE = 41.1 t/ha, R2 = 0.0272, Mean error = 12.8 t/ha, Mean absolute error = 19.6 t/ha

Contact Point:
Data holder: Juan C.Rey
Institution: Sociedad Venezolana de la Ciencia del Suelo (SVCS)
Email or website: svcs.org
D194: Viet Nam

GSOCmap layer source:
Map source: Country submission

Data specifications:
Number of samples: 1024
Time frame: after 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Measured
Coarse fragments method: Measured
Citation: N/A

Methodological specifications:
Mapping technique: Digital soil mapping
Mapping method: Random forest
Mapping method details: Random forest
Validation: R2=0.34; MAE=13.65; RMSE=21.44.

Contact Point:
Data holder: Vu Manh Quyet
Institution: Soils and Fertilizers Research Institute
Email or website: quyetvm.sfri@mard.gov.vn; vmquyet@gmail.com

D195: Yemen

GSOCmap layer source:
Map source: GSP gap-filling
Data specifications:

Number of samples: 270
Time frame: before 1990
Soil Organic Carbon method: wet oxidation
Bulk density method: Pedotransfer functions
Coarse fragments method: Measured/Estimated

Methodological specifications:

Mapping technique: Digital soil mapping
Mapping method: Support vector machines
Mapping method details: Support vector machines model based on the ensemble globally available data from Algeria, Chad, Egypt, Iraq, Jordan, Lebanon, Libya, Mali, Mauritania, Morocco, Niger, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, United Arab Emirates, Western Sahara and Yemen
Validation: MAE=6.8 t/ha; RMSE = 10.94 t/ha

Contact Point:

Data holder: Global Soil Partnership
Institution: Global Soil Partnership

D196: Zambia

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 460  
Time frame: before 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: Measured/Estimated  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe  
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  

D197: Zimbabwe

GSOCmap layer source:

Map source: GSP gap-filling
Data specifications:

Number of samples: 179  
Time frame: before and after 1990  
Soil Organic Carbon method: wet oxidation  
Bulk density method: mixed  
Coarse fragments method: Measured/Estimated  

Methodological specifications:

Mapping technique: Digital soil mapping  
Mapping method: Random forest  
Mapping method details: Random forest model based on the ensemble globally available data from Angola, Botswana, Cameroon, Congo, Gabon, Guinea, Burundi, Central African Republic, Democratic Republic of the Congo, Kenya, Malawi, Namibia, South Africa, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe  
Validation: MAE=27 t/ha; RMSE=43.7 t/ha; R2=0.19.

Contact Point:

Data holder: Global Soil Partnership  
Institution: Global Soil Partnership  
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- Schweizerische Eidgenossenschaft
- Confédération suisse
- Confederația Svizera
- Confederazione svizzera
- Swiss Confederation