SoilGrids

Using big data solutions and machine learning algorithms for global soil mapping

L. M. de Sousa N. H. Batjes G. B. M. Heuvelink B. Kempen L. Poggio

December 11, 2018

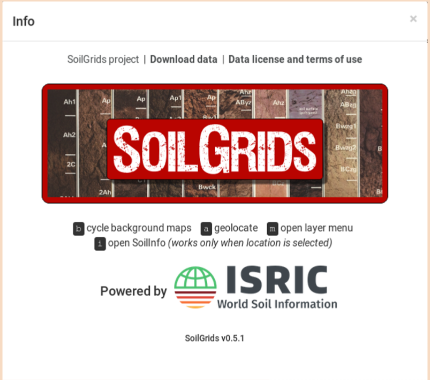
Outline

1. What is SoilGrids
2. The Mapping Process
3. How to access SoilGrids
4. Applications
5. What's ahead

What is SoilGrids

What is SoilGrids

Global soil mapping



- Series of global grids with predictions of soil types and properties
  - seven standard depths
- High resolution: $\approx$ 8 arcseconds
  - 250 m at the Equator
- A product of Machine Learning
- Open Access and Open Source
- Increasingly used in global studies
- User support provided

Brief history of SoilGrids

Evolution

- Soil properties predictions for Africa at 32 arcseconds resolution.
- Predictions for the World at 32 arcseconds resolution.
- Predictions for Africa at 8 arcseconds resolution.
- For the World at 8 arcseconds resolution.
- Increasing data volume and geographic coverage.
- Increasing computational demands.
- Constant methodological improvement.

Which data are available

SoilGrids predicted variables

Site characteristics	Physical prop.	Chemical prop.	Classification
• Depth to bedrock • Probability of R horizon • Soil organic carbon stock	• Bulk density • Clay content • Coarse fragments • Silt content • Sand content	• Cation exchange capacity • Organic carbon content • pH (H20 & KCl)	• World Reference Base • USDA Soil Taxonomy

Which data are available

SoilGrids predicted variables

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▶ Seven standard depth levels for physical and chemical properties.

Which data are available

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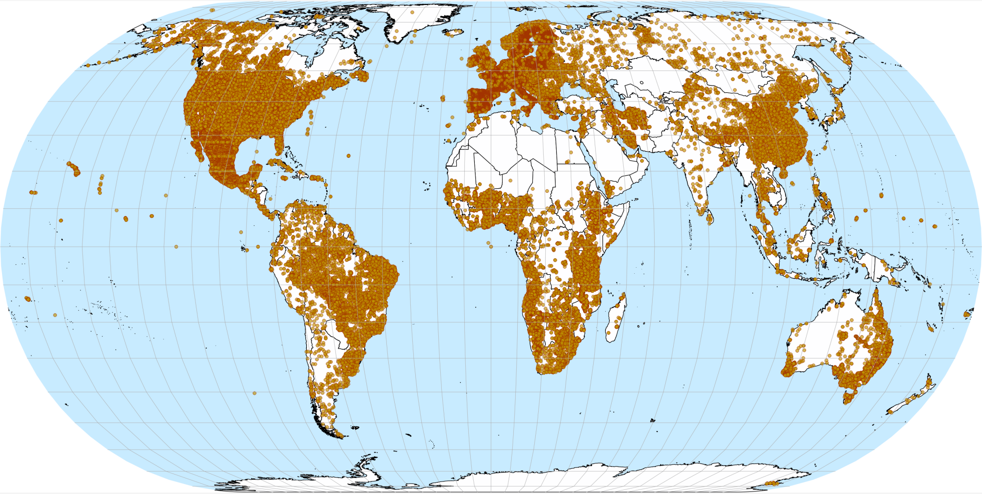
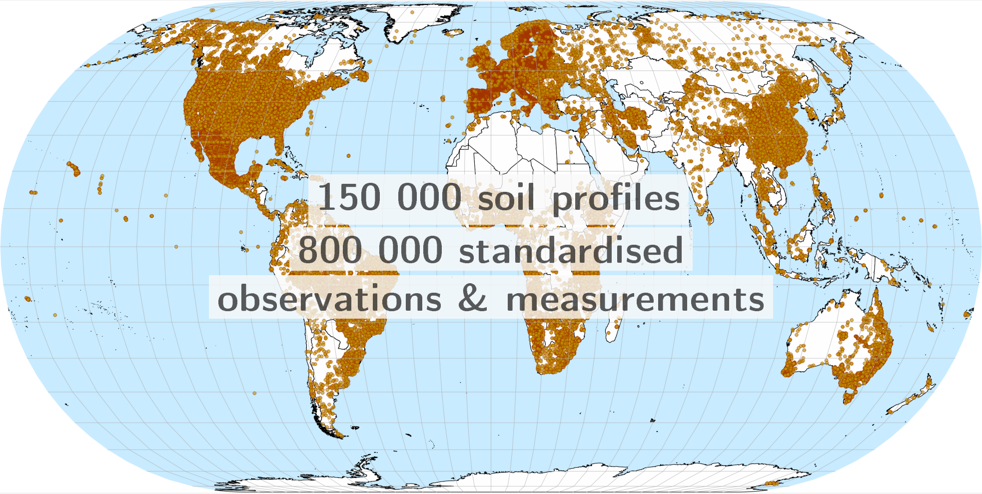
- Seven standard depth levels for physical and chemical properties.
- More than 180 global rasters.

The Mapping Process

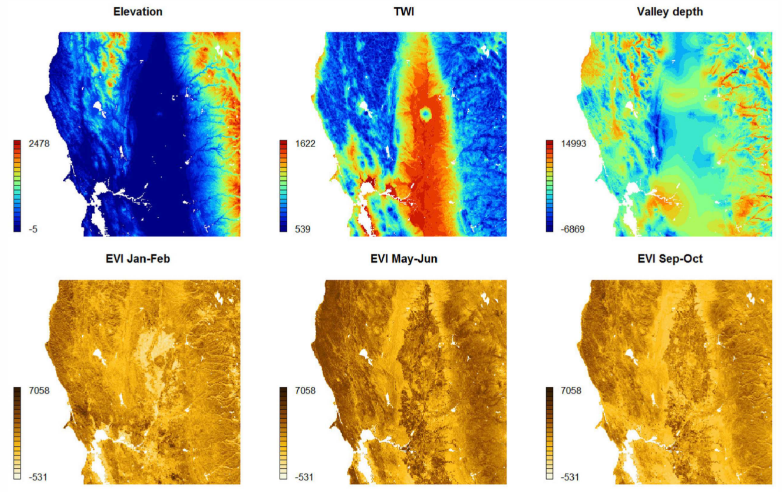
Soil Profile database



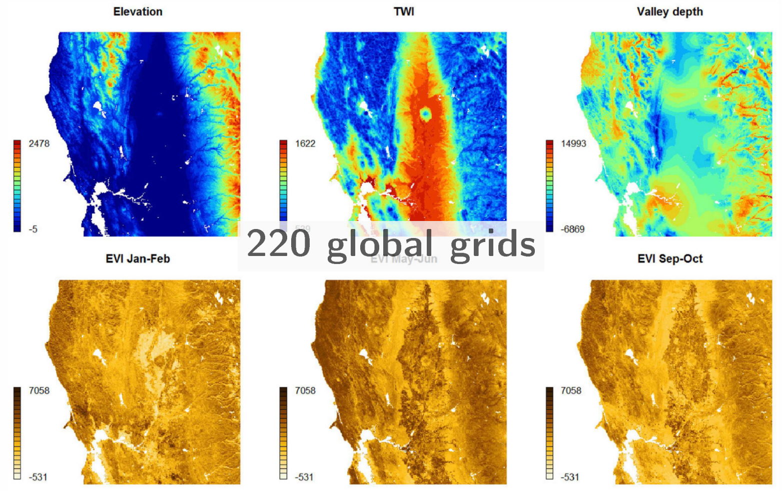
Soil Profile database



Environmental Covariates



Environmental Covariates



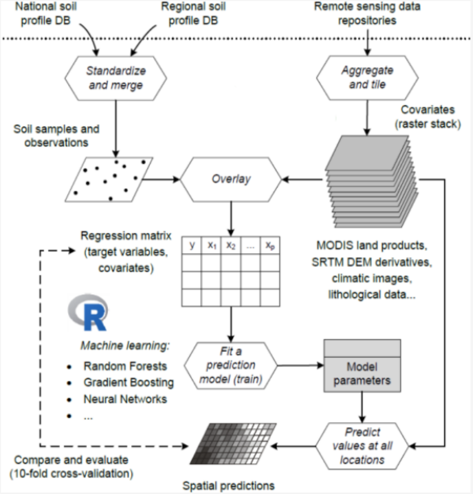
220 global grids

Environmental Covariates

Multiple sources

- Long-term averaged monthly mean and stand. dev. of climatic variables (MODIS).
- DEM-derived surfaces: slope, profile curvature, valley bottom flatness, valley depth, negative and positive topographic openness, etc.
- Long-term averaged monthly mean and standard deviation of the MODIS Enhanced Vegetation Index (EVI).
- Lithologic units based on Global Lithological Map (GLiM).
- Landform classes based on the USGS Map of Global Ecological Land Units.
- Global water table depth.
- Land cover classes for 2014
- ...

Digital Soil Mapping workflow



- 12 000 CPU-hours
- 256 GB of RAM (bare minimum)
- 2 TB of high-speed HDD
- 40 different R packages
- over 20 other libraries/programmes

github.com/ISRICWorldSoil/SoilGrids250m

In the Scientific press

PLOS ONE

RESEARCH ARTICLE

SoilGrids250m: Global gridded soil information based on machine learning

Tomislav Hengl[1]*, Jorge Mendes de Jesus[1], Gerard B. M. Heuvelink[1], Maria Ruiperez Gonzalez[1], Milan Kilibarda[2], Aleksandar Blagotić[3], Wei Shangguan[4], Marvin N. Wright[5], Xiaoyuan Geng[6], Bernhard Bauer-Marschallinger[7], Mario Antonio Guevara[8], Rodrigo Vargas[8], Robert A. MacMillan[9], Niels H. Batjes[1], Johan G. B. Leenaars[1], Eloi Ribeiro[1], Ichsani Wheeler[10], Stephan Mantel[1], Bas Kempen[1]

1 ISRIC — World Soil Information, Wageningen, the Netherlands, **2** Faculty of Civil Engineering, University of Belgrade, Belgrade, Serbia, **3** GILab Ltd, Belgrade, Serbia, **4** School of Atmospheric Sciences, Sun Yat-sen University, Guangzhou, China, **5** Institut für Medizinische Biometrie und Statistik, Lübeck, Germany, **6** Agriculture and Agri-Food Canada, Ottawa (Ontario), Canada, **7** Department of Geodesy and Geoinformation, Vienna University of Technology, Vienna, Austria, **8** University of Delaware, Newark (DE), United States of America, **9** LandMapper Environmental Solutions Inc., Edmonton (Alberta), Canada, **10** Envirometrix Inc., Wageningen, the Netherlands

* tom.hengl@isric.org

Check for updates

Citation: Hengl T, Mendes de Jesus J, Heuvelink GBM, Ruiperez Gonzalez M, Kilibarda M, Blagotić A, et al. (2017) SoilGrids250m: Global gridded soil information based on machine learning. PLoS ONE 12(2): e0169748. doi:10.1371/journal.pone.0169748

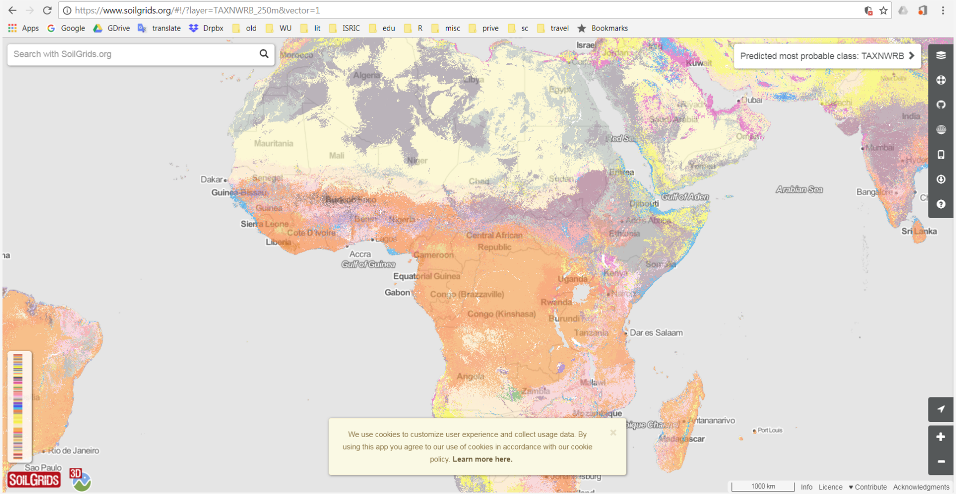
Editor: Ben Bond-Lamberty, Pacific Northwest National Laboratory, UNITED STATES

Abstract

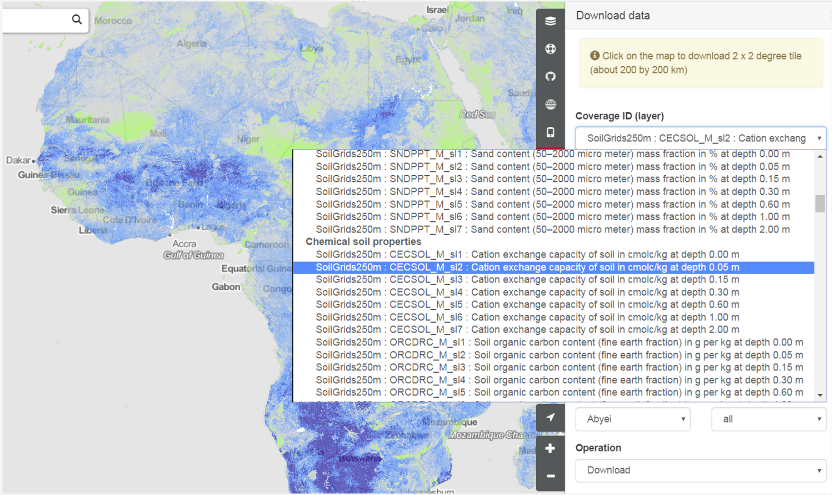
This paper describes the technical development and accuracy assessment of the most recent and improved version of the SoilGrids system at 250m resolution (June 2016 update). SoilGrids provides global predictions for standard numeric soil properties (organic carbon, bulk density, Cation Exchange Capacity (CEC), pH, soil texture fractions and coarse fragments) at seven standard depths (0, 5, 15, 30, 60, 100 and 200 cm), in addition to predictions of depth to bedrock and distribution of soil classes based on the

How to access SoilGrids

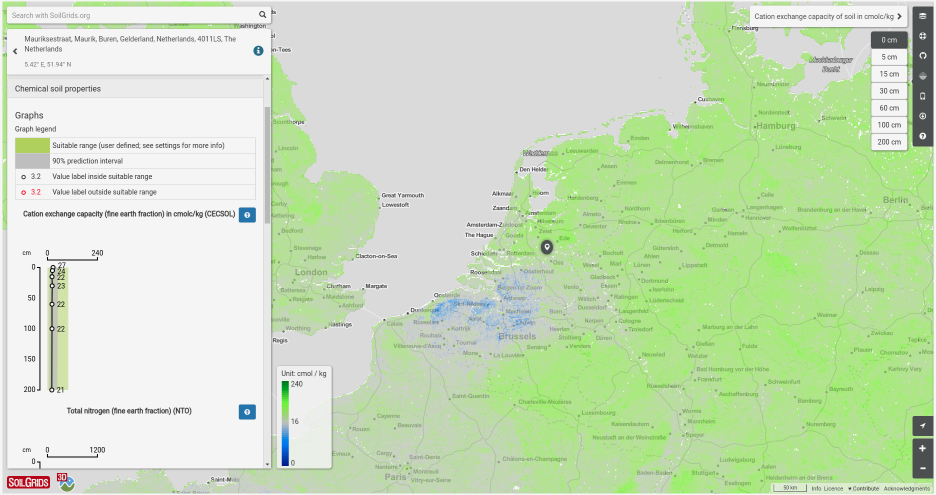
soilgrids.org



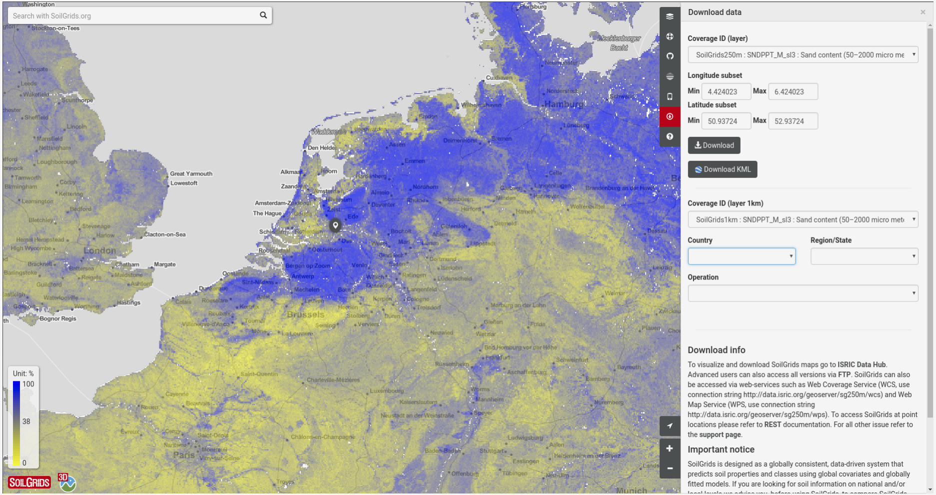
soilgrids.org



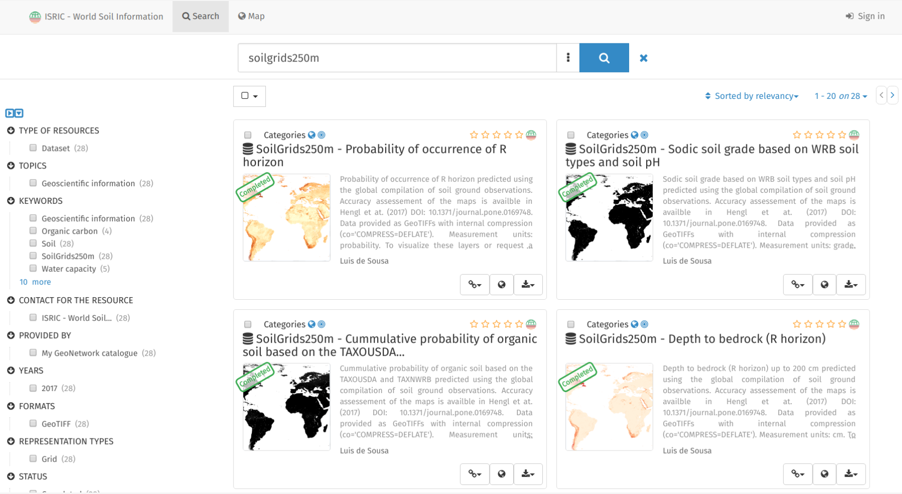
soilgrids.org



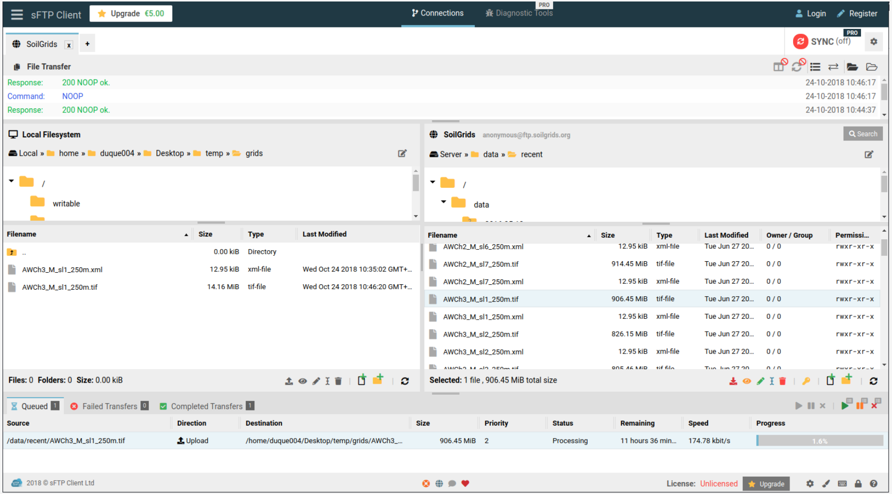
soilgrids.org



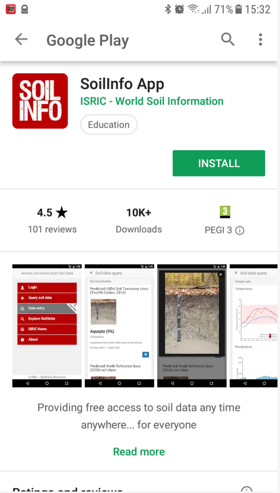
data.isric.org - OGC web services

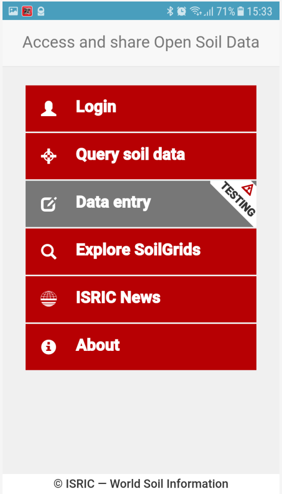


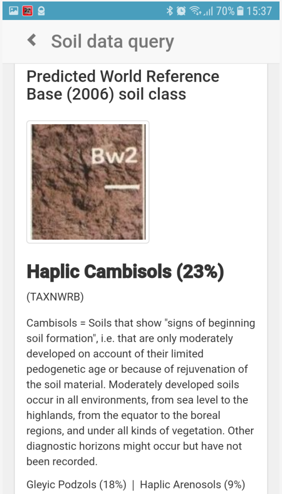
ftp.soilgrids.org



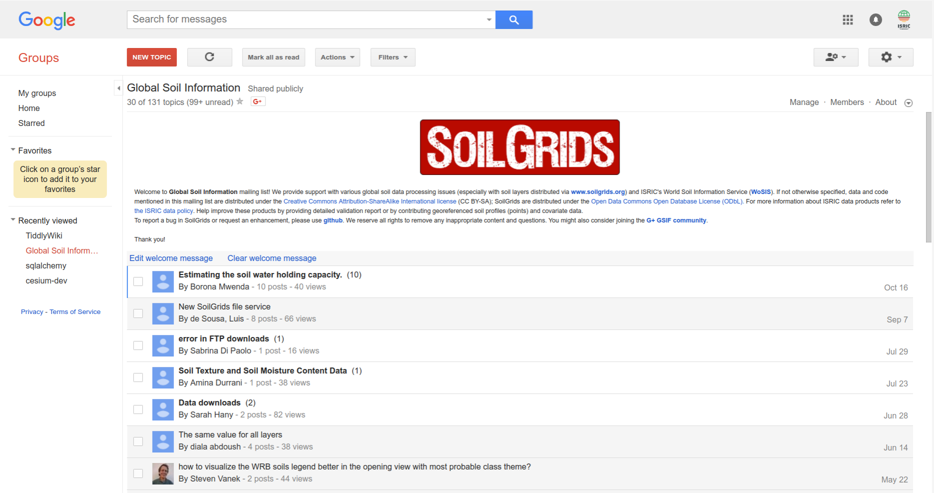
SoilInfo mobile phone app







User support



Applications

AfSIS - mapping soil nutrients

Nutr Cycl Agroecosyst (2017) 109:77–102
DOI 10.1007/s10705-017-9870-x

CrossMark

ORIGINAL ARTICLE

Soil nutrient maps of Sub-Saharan Africa: assessment of soil nutrient content at 250 m spatial resolution using machine learning

Tomislav Hengl · Johan G. B. Leenaars · Keith D. Shepherd · Markus G. Walsh · Gerard B. M. Heuvelink · Tekalign Mamo · Helina Tilahun · Ezra Berkhout · Matthew Cooper · Eric Fegraus · Ichsani Wheeler · Nketia A. Kwabena

Received: 19 January 2017 / Accepted: 28 July 2017 / Published online: 2 August 2017

Abstract Spatial predictions of soil macro and micro-nutrient content across Sub-Saharan Africa at 250 m spatial resolution and for 0–30 cm depth (Fe), manganese (Mn), zinc (Zn), copper (Cu), aluminum (Al) and boron (B). Model training was performed using soil samples from ca. 59,000 loca-

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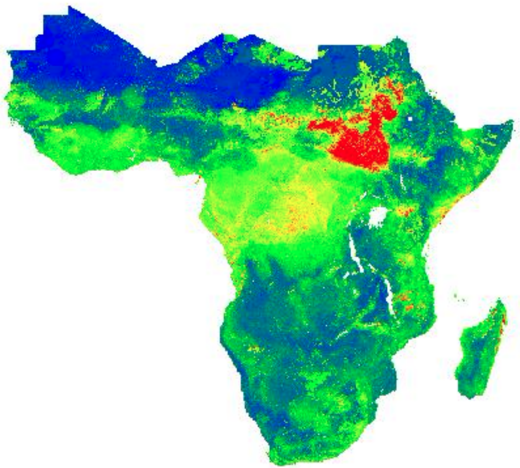

Soil water holding capacity

ELSEVIER

Geoderma
Volume 324, 15 August 2018, Pages 18-36

Mapping rootable depth and root zone plant-available water holding capacity of the soil of sub-Saharan Africa

Johan G.B. Leenaars [a], Lieven Claessens [b, c, d], Gerard B.M. Heuvelink [a, d], Tom Hengl [a], Maria Ruiperez González [a], Lenny G.J. van Bussel [e, f], Nicolas Guilpart [g, h], Haishun Yang [h], Kenneth G. Cassman [h]

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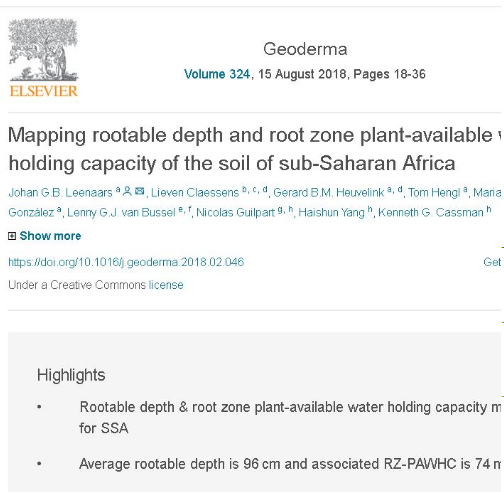
Highlights

- Rootable depth & root zone plant-available water holding capacity mapped for SSA
- Average rootable depth is 96 cm and associated RZ-PAWHC is 74 mm.

Soil water holding capacity



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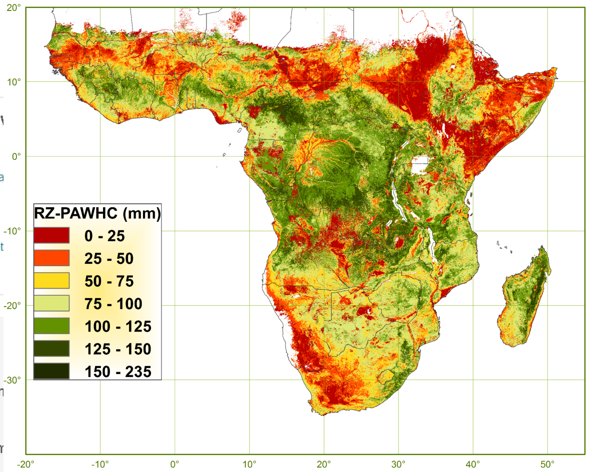
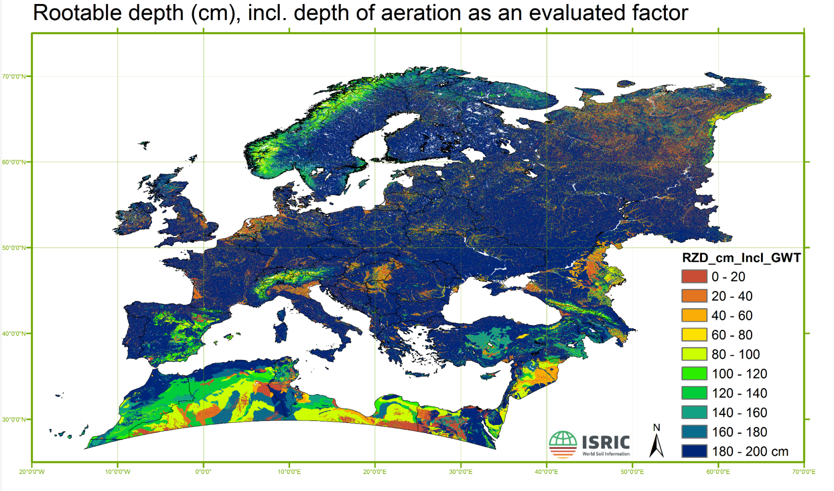


MARSOP - rootable depth



Soil Carbon modelling

Environmental Research Letters

LETTER • OPEN ACCESS • FEATURED ARTICLE

A global map of mangrove forest soil carbon at 30 m spatial resolution

Jonathan Sanderman[1,21], Tomislav Hengl[2], Greg Fiske[1], Kylen Solvik[1], Maria Fernanda Adame[3], Lisa Benson[5,6], Jacob J Bukoski[7], Paul Carnell[8], Miguel Cifuentes-Jara[9], Daniel Donato[19]

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Published 30 April 2018 • © 2018 The Author(s). Published by IOP Publishing Ltd

Environmental Research Letters, Volume 13, Number 5

Focus on The Role of Forests and Soils in Meeting Climate Change Mitigation Goals

Abstract

With the growing recognition that effective action on climate change will require a combination of emissions reductions and carbon sequestration, protecting, enhancing and restoring natural carbon sinks have become political priorities. Mangrove forests are considered some of the most carbon-dense ecosystems in the world with most of the carbon stored in the soil. In order for mangrove forests to be included in climate mitigation efforts, knowledge of the spatial distribution of mangrove soil carbon stocks are critical. Current global estimates do not capture enough of the finer scale variability that would be required to inform local decisions on siting protection and restoration

Soil Carbon debt

PNAS Proceedings of the National Academy of Sciences of the United States of America

Keyword, Author, or DOI

Advanced Search

Soil carbon debt of 12,000 years of human land use

Jonathan Sanderman, Tomislav Hengl, and Gregory J. Fiske

PNAS September 5, 2017 114 (36) 9575-9580; published ahead of print August 21, 2017
https://doi.org/10.1073/pnas.1706103114

Edited by William H. Schlesinger, Cary Institute of Ecosystem Studies, Millbrook, NY, and approved July 14, 2017 (received for review April 12, 2017)

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This article has a correction. Please see:
Correction for Sanderman et al., Soil carbon debt of 12,000 years of human land use

Article | Figures & SI | Info & Metrics | PDF

Significance

Land use and land cover change has resulted in substantial losses of carbon from soils globally, but credible estimates of how much soil carbon has been lost have been difficult to generate. Using a data-driven statistical model and the History Database of the Global Environment v3.2 historic land-use dataset, we estimated that agricultural land uses have resulted in the loss of 133 Pg C from the soil. Importantly, our maps indicate hotspots of soil carbon loss, often associated with major cropping regions and degraded grazing lands, suggesting that there are identifiable regions that should be targets for soil carbon restoration efforts.

More Articles of This Classification

Physical Sciences
- Deciphering the structure of the condensin protein complex
- Universality of jamming of nonspherical particles
- Potential downside of high initial visual acuity

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Sustainability Science
- Deciphering the structure of the condensin protein complex

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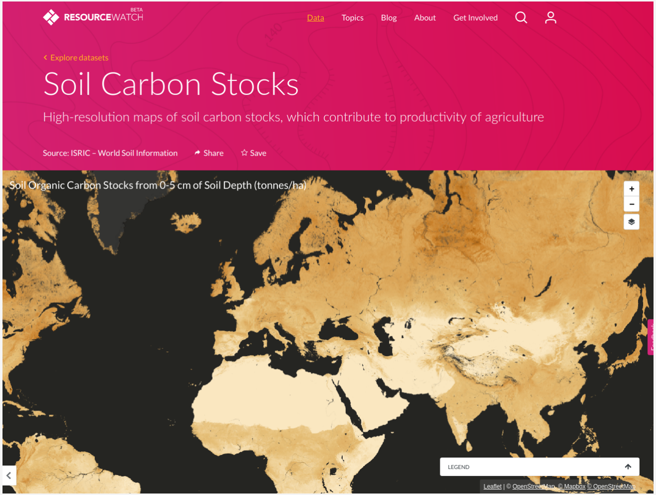
Soil Carbon mapping



Plant Science

PLOS ONE

RESEARCH ARTICLE

Using worldwide edaphic data to model plant species niches: An assessment at a continental extent

Santiago José Elías Velazco[1]*, Franklin Galvão[1], Fabricio Villalobos[2], Paulo De Marco Júnior[3]

1 Laboratório de Ecologia Florestal, Departamento de Ciências Agrarias, Universidade Federal do Paraná, Curitiba, Paraná, PR, Brasil, **2** Laboratorio de Macroecología Evolutiva, Red de Biología Evolutiva, Instituto de Ecología, AC, Xalapa, Veracruz, México, **3** Laboratório de Teoria, Metacomunidades e Ecologia de Paisagens, Departamento de Ecologia, ICB, Universidade Federal de Goiás, Goiânia, GO, Brasil

* sjevelazco@gmail.com

OPEN ACCESS

Citation: Velazco SJE, Galvão F, Villalobos F, De Marco Júnior P (2017) Using worldwide edaphic data to model plant species niches: An assessment at a continental extent. PLoS ONE 12(10): e0186025. https://doi.org/10.1371/journal.pone.0186025

Abstract

Ecological niche modeling (ENM) is a broadly used tool in different fields of plant ecology. Despite the importance of edaphic conditions in determining the niche of terrestrial plant species, edaphic data have rarely been included in ENMs of plant species perhaps because such data are not available for many regions. Recently, edaphic data has been made available at a global scale allowing its potential inclusion and evaluation on ENM performance for plant species. Here, we take advantage of such data and address the following main questions: What is the influence of distinct predictor variables (e.g. climatic vs edaphic) on different ENM algorithms? and what is the relationship between the performance of different

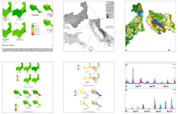
Hydrologic modelling

Outline

Highlights
Abstract
Graphical abstract
Keywords
1. Introduction
2. Methodology
3. Application
4. Summary and conclusion
References

Show full outline

Figures (8)



Show all figures

Tables (4)

Table 1-a
Table 1-b
Table 2
Table 3

ELSEVIER

Science of The Total Environment
Volumes 631–632, 1 August 2018, Pages 279-288

Integrating global land-cover and soil datasets to update saturated hydraulic conductivity parameterization in hydrologic modeling

T. Trinh [a, g], M.L. Kavvas [a], K. Ishida [b], A. Ercan [c], Z.Q. Chen [d], M.L. Anderson [d], C. Ho [e], T. Nguyen [f]

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https://doi.org/10.1016/j.scitotenv.2018.02.267

Highlights

- This manuscript proposes an approach that can enables assimilation of coarse soil parameters by finer LULC datasets.
- The approach has been incorporated into the WEHY model to simulate hydrologic conditions using different soil datasets.
- The results of this study suggest that the proposed approach can provide a fine resolution soil dataset.
- This approach can improve the estimation of soil hydraulic parameters and the performance of hydrologic modeling.
- The new approach of this study can be applied in many parts of the world by means of the global soil and LULC databases.

SoilGrids in peer reviewed literature

Citations per area, by Web of Science

Research area	N	Research area	N
Environmental Sciences Ecology	84	Remote Sensing	9
Agriculture	82	Biodiversity Conservation	8
Geology	46	Evolutionary Biology	8
Water Resources	30	Forestry	8
Science Technology Other Topics	29	Geography	7
Meteorology Atmospheric Sciences	21	Computer Science	6
Physical Geography	16	Marine Freshwater Biology	5
Plant Sciences	11		

What's ahead

Future developments

Scientific

- Quantifying and mapping Uncertainties.
- Space-time mapping (organic carbon).
- Derived soil properties: support evaluation of soil functions.
- Cartographic projection: shift to equal-area.
- Develop covariates from the Sentinel programme.

Future developments

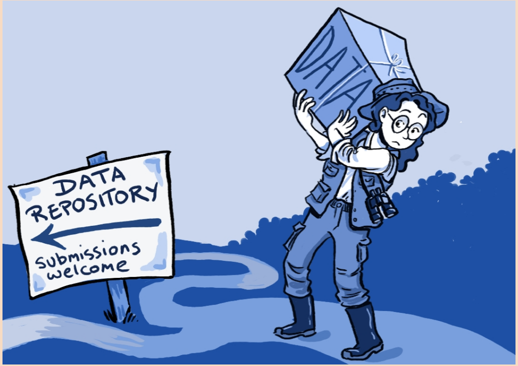
Technical

- Modern Machine Learning engines:
  - mlr (R);
  - Dask-ML (Python);
  - Julia.
- New file service in development.
- Modernisation of the web site.
- Raster tilling with VRT.

A collaborative effort

SoilGrids improves with Community contributions

- Feedback on predictions.
- Improving soil observations & measurements:
  - better quality;
  - wider spatial coverage.
- Share your data: https://www.isric.org/explore/share



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World Soil Information

Thank you!

www.isric.org