SoilGrids250m and SoilInfo App:
providing public access to soil information across borders

ISRIC World Soil Information

T. (Tom) Hengl <tom.hengl@isric.org>

SOILGRIDS

A system for automated global soil mapping

www.soilgrids.org

ISRIC

World Soil Information

Thanks to:

- **ISRIC staff:**

  Jorge Mendes de Jesus, **Maria** Ruiperez Gonzalez, **Bas** Kempen, **Robert** McMillan, **Niels** Batjes, **Eloi** Ribeiro, **Gerard** Heuvelink, **Johan** Leenaars and others

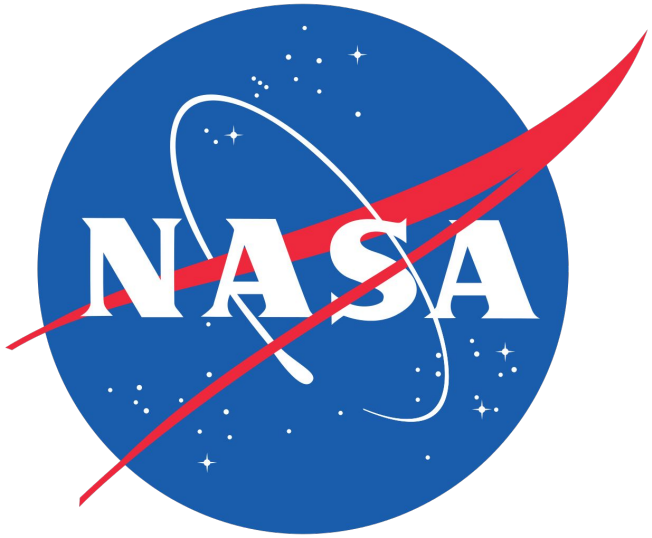
- **GILab (Belgrade):**

  Aleksander Blagotic**, Milan** Kilibarda

- **External collaborators:**

  Mario Antonio Guevarra (University of Delaware), Amanda Ramcharan (Penn State University), David Rossiter …

Big thanks to:



AfSIS project

Bill & Melinda Gates Foundation

Business Operation

Bill & Melinda Gates Foundation is one of the largest private foundations in the world, founded by Bill and Melinda Gates. It was launched in 2000 and is said to be the largest transparently operated private foundation in the world.
Wikipedia

Nonprofit category: Private Grantmaking Foundations

Founded: 2000

Assets: 36.79 billion USD (2010)

Income: 53 billion USD (2010)

Founders: Melinda Gates, Bill Gates

Also thanks to:

Center for International Forestry Research

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP

UNEP

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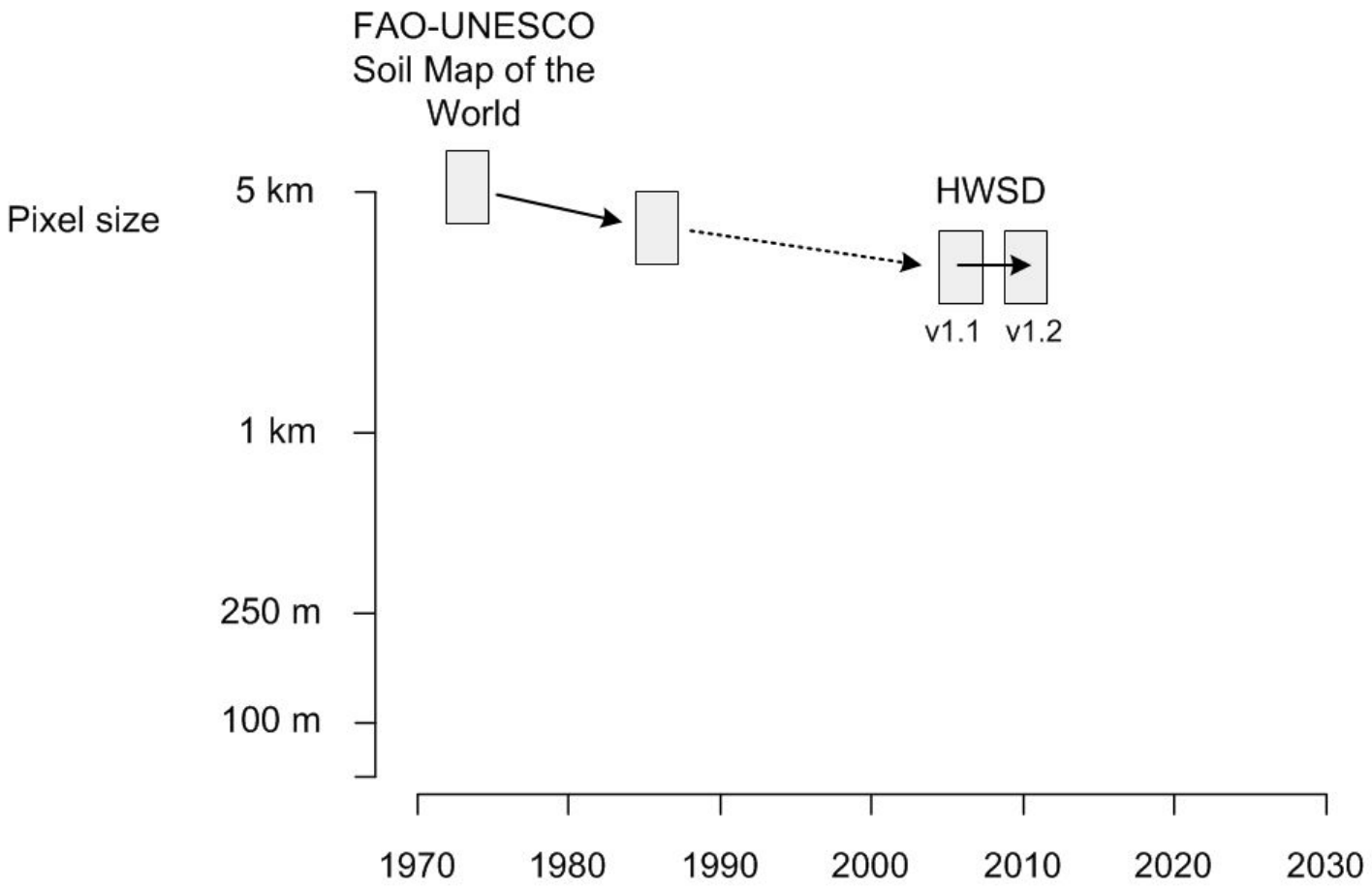
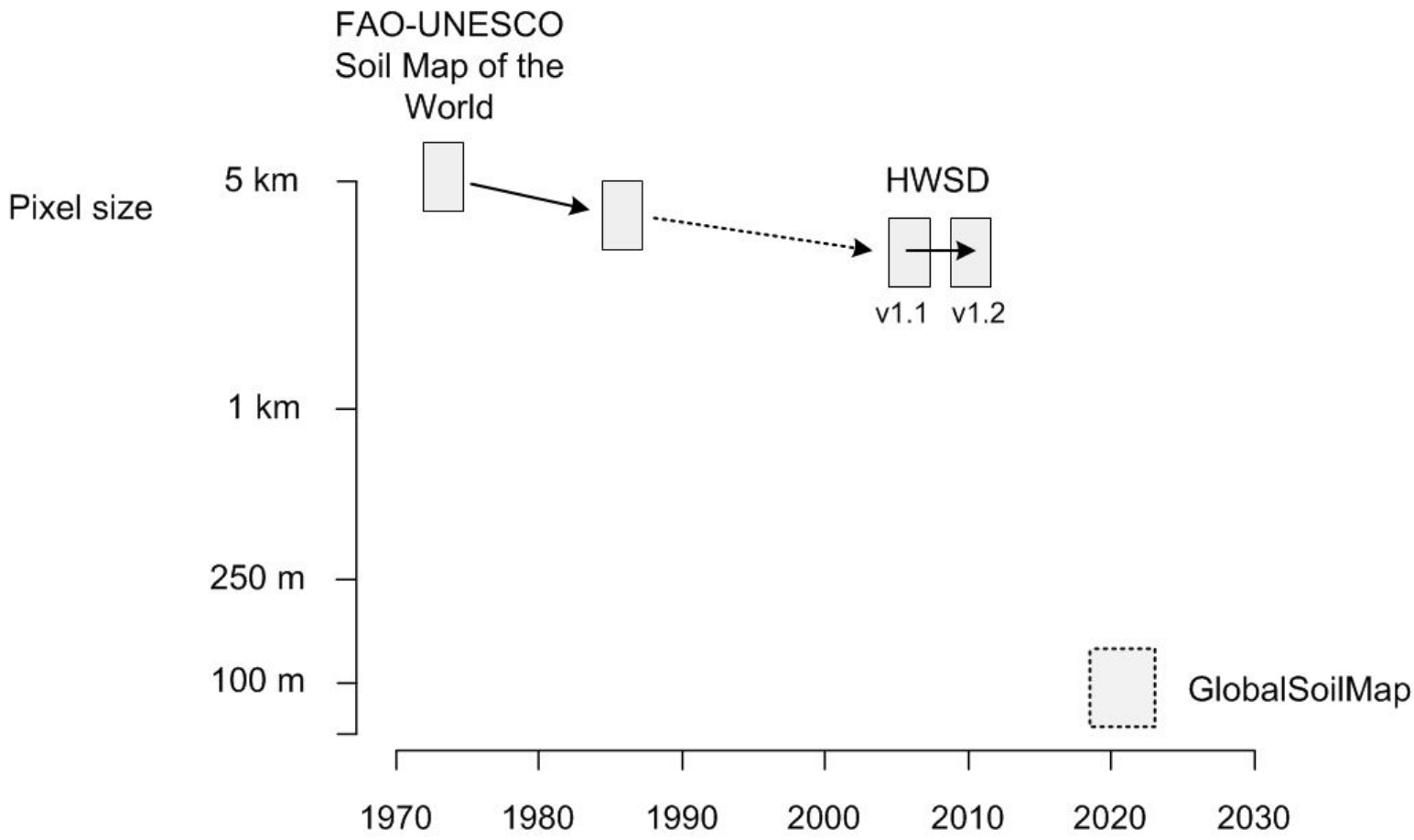
A bit of history

Why SoilGrids?



Why SoilGrids?



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Science 7 August 2009:
Vol. 325 no. 5941 pp. 680-681
DOI: 10.1126/science.1175084

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POLICY FORUM

ENVIRONMENTAL SCIENCE

Digital Soil Map of the World

Pedro A. Sanchez[1,*], Sonya Ahamed[1], Florence Carré[2], Alfred E. Hartemink[3], Jonathan Hempel[4], Jeroen Huising[5], Philippe Lagacherie[6], Alex B. McBratney[7], Neil J. McKenzie[8], Maria de Lourdes Mendonça-Santos[9], Budiman Minasny[7], Luca Montanarella[2], Peter Okoth[5], Cheryl A. Palm[1], Jeffrey D. Sachs[1], Keith D. Shepherd[10], Tor-Gunnar Vågen[10], Bernard Vanlauwe[5], Markus G. Walsh[1], Leigh A. Winowiecki[1] and Gan-Lin Zhang[11]

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[2]Joint Research Centre, European Commission, 21020 Ispra, VA, Italy.
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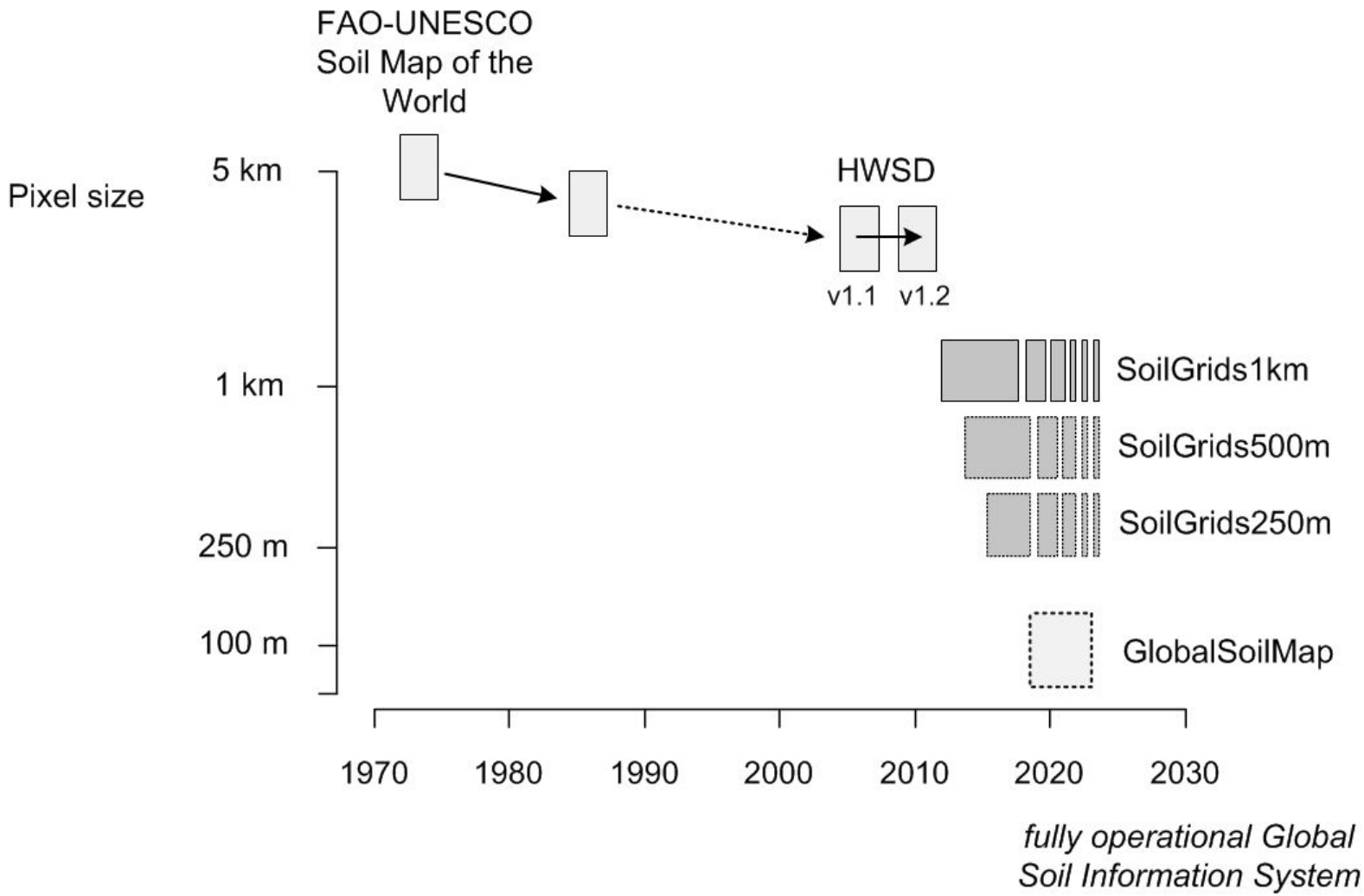
[5]Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture, Post Office Box 30677, Nairobi, Kenya.
[6]Laboratoire d'Étude des Interactions Sols-Agrosystèmes-Hydrosystèmes, L'Institut National pour la Recherche Agronomique, Institut de Recherche pour Développement, SupAgro, 34060 Montpellier 1, France.
[7]Faculty of Agriculture, Food and Natural Resources, The University of Sydney, Sydney, NSW 2006, Australia.
[8]Commonwealth Scientific and Industrial Research Organization (CSIRO) Land and Water, Government Post Office Box 1666, Canberra, ACT, 2601, Australia.
[9]EMBRAPA–Brazilian Agricultural Research Corporation, The National Center of Soil Research, Rua Jardim Botânico, 1024, 22.460-000, Rio de Janeiro, Brazil.
[10]World Agroforestry Centre, Post Office Box 30677–00100, Nairobi 00100, Kenya.
[11]State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science of the Chinese Academy of Sciences, Nanjing, China.
[*]Author for correspondence. E-mail: psanchez{at}ei.columbia.edu

Soils are increasingly recognized as major contributors to ecosystem services such as food production and climate regulation (*1*, *2*), and demand for up-to-date and relevant soil information is soaring. But communicating such information among diverse audiences remains challenging because of inconsistent use of technical jargon, and outdated, imprecise methods. Also, spatial resolutions of soil maps for most parts of the world are too low to help with practical land management. While other earth sciences (e.g., climatology, geology) have become more quantitative and have taken advantage of the digital revolution, conventional soil mapping delineates space mostly

Why SoilGrids? To fill in the gap.



Rome, FAO (Gerda Verburg twitter)

SoilGrids were officially launched on 4th of Dec 2013 at FAO, Rome

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

SoilGrids1km — Global Soil Information Based on Automated Mapping

Tomislav Hengl, Jorge Mendes de Jesus, Robert A. MacMillan, Niels H. Batjes, Gerard B. M. Heuvelink, Eloi Ribeiro, Alessandro Samuel-Rosa, Bas Kempen, Johan G. B. Leenaars, Markus G. Walsh, Maria Ruiperez Gonzalez

Published: August 29, 2014 • DOI: 10.1371/journal.pone.0105992

Abstract

Background

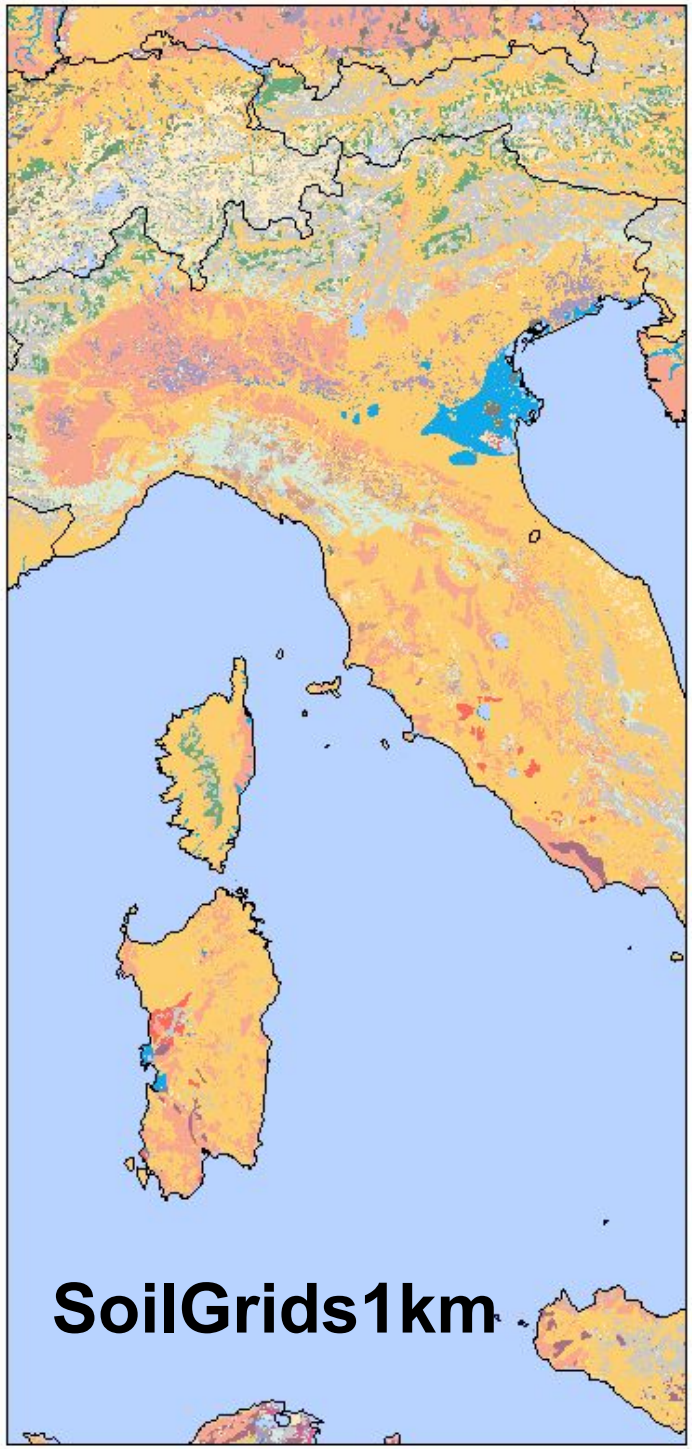
Soils are widely recognized as a non-renewable natural resource and as biophysical carbon sinks. As such, there is a growing requirement for global soil information. Although several global soil information systems already exist, these tend to suffer from inconsistencies and limited spatial detail.

Methodology/Principal Findings

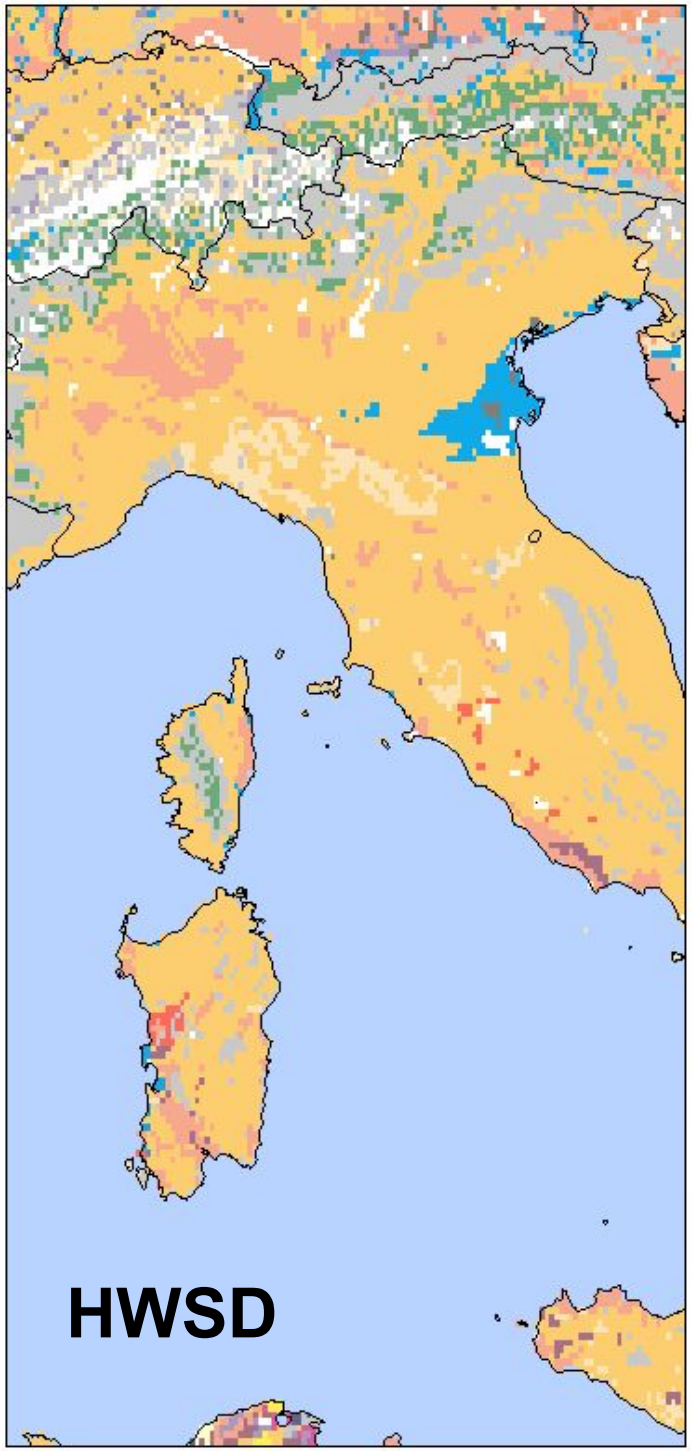
We present SoilGrids1km — a global 3D soil information system at 1 km resolution — containing spatial predictions for a selection of soil properties (at six standard depths): soil organic carbon (g kg−1), soil pH, sand, silt and clay fractions (%), bulk density (kg m−3), cation-exchange capacity (cmol+/kg), coarse fragments (%), soil organic carbon stock (t ha−1), depth to bedrock (cm), World Reference Base soil groups, and USDA Soil Taxonomy suborders. Our predictions are based on global spatial prediction models which we fitted, per soil variable,

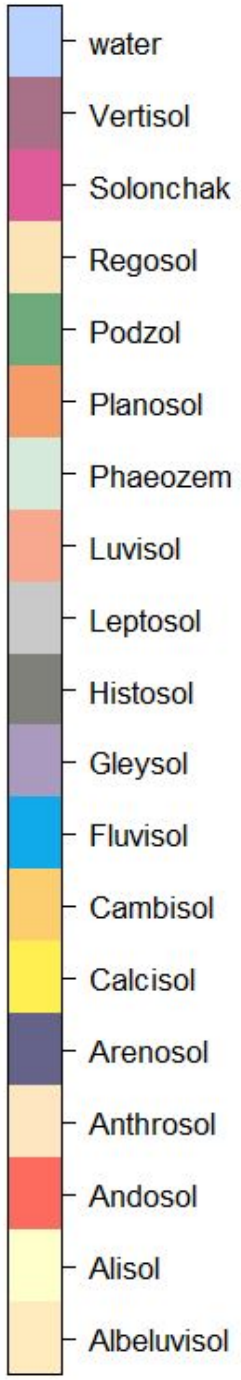
Subject Areas

- Agricultural soil scie...
- Clay mineralogy
- Deserts
- Forecasting
- Remote sensing
- Surface temperature
- Taxonomy
- Urban areas

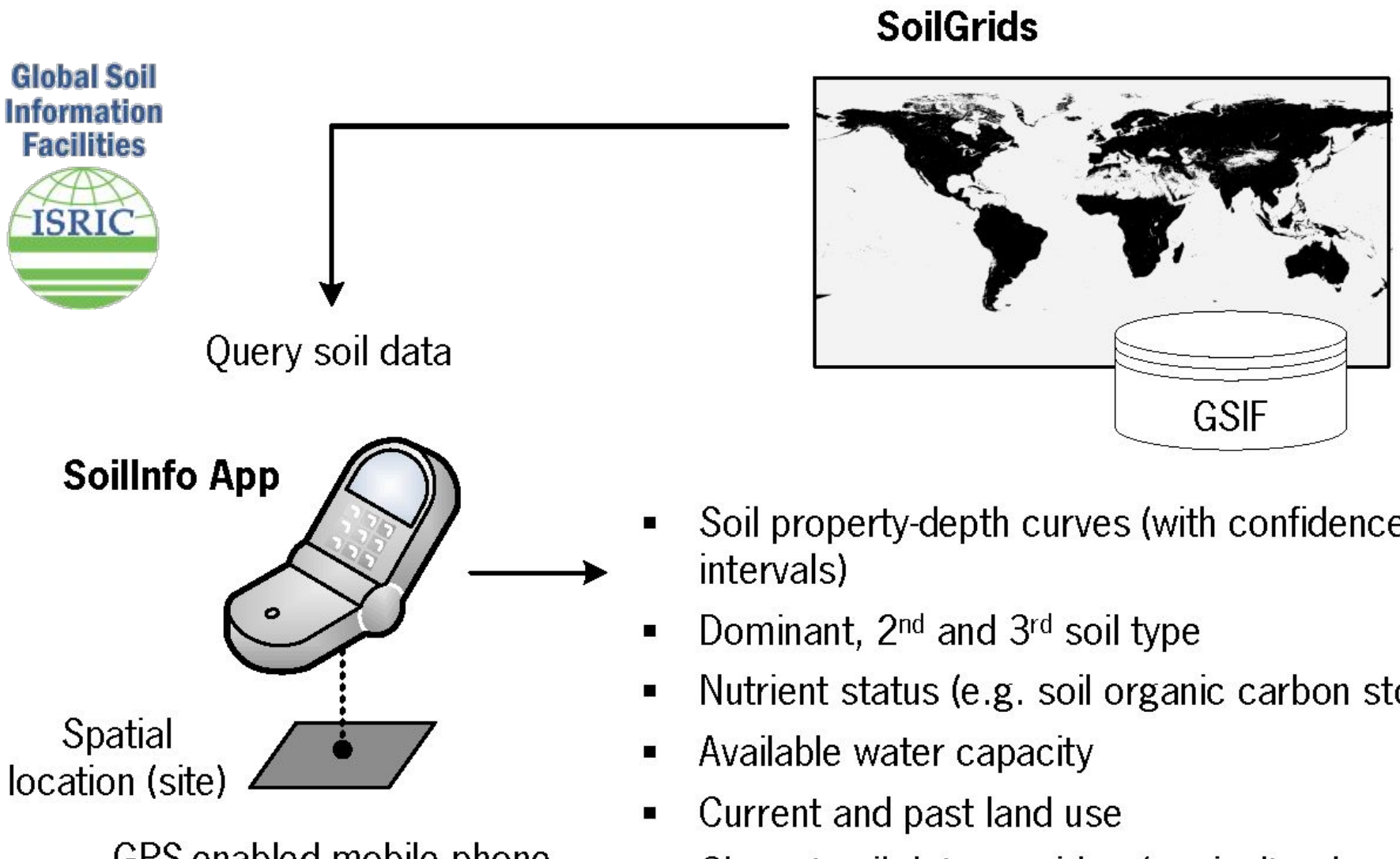

SoilGrids1km


Vertisol
Umbrisol
Solonetz
Solonchak
Regosol
Podzol
Planosol
Phaeozem
Nitisol
Luvisol
Lixisol
Leptosol
Kastanozem
Histosol
Gleysol
Fluvisol
Ferralsol
Chernozem
Cambisol
Calcisol
Arenosol
Andosol
Alisol
Albeluvisol
Acrisol
water


HWSD


water
Vertisol
Solonchak
Regosol
Podzol
Planosol
Phaeozem
Luvisol
Leptosol
Histosol
Gleysol
Fluvisol
Cambisol
Calcisol
Arenosol
Anthrosol
Andosol
Alisol
Albeluvisol

Global Soil Information Facilities



- Soil property-depth curves (with confidence intervals)
- Dominant, 2nd and 3rd soil type
- Nutrient status (e.g. soil organic carbon stock)
- Available water capacity
- Current and past land use
- Closest soil data provider / agricultural extension service

SoilGrids1km: criticism

- **Artifacts** (mainly propagating from HWSD)
- Some soil properties are **smoothed-out** (regression only) **over-prediction of low values** (Organic carbon) / under-prediction of high values (see e.g. doi: 10.1016/j.geoderma.2015.08.035)
- **Only linear** soil property-depth relationships
- No predictions for deserts (are deserts soil bodies?)

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When it comes to creating a great work of art, practice makes perfect, writes Matthew Syed.

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RESEARCH ARTICLE

Mapping Soil Properties of Africa at 250 m Resolution: Random Forests Significantly Improve Current Predictions

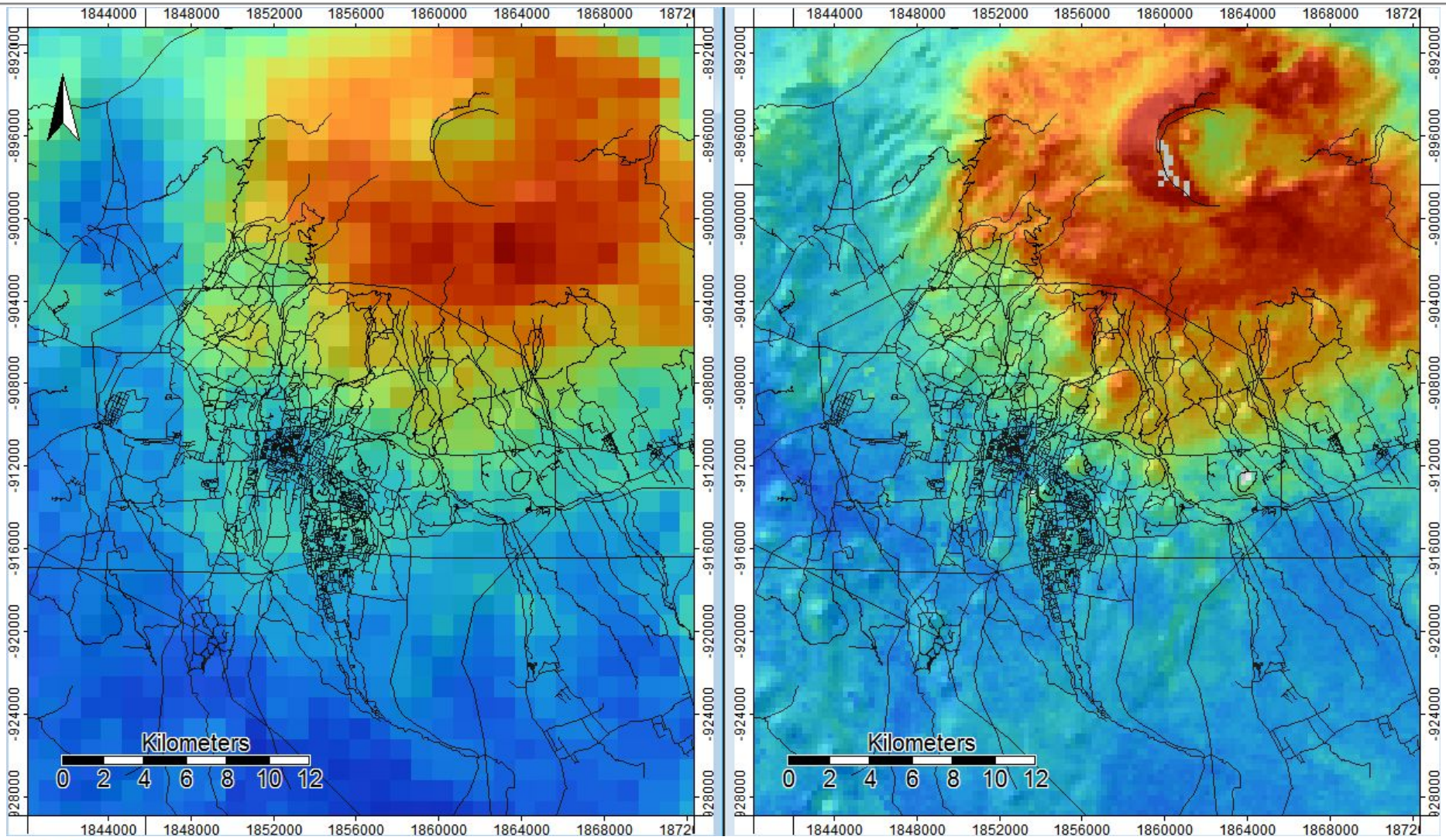
Tomislav Hengl, Gerard B. M. Heuvelink, Bas Kempen, Johan G. B. Leenaars, Markus G. Walsh, Keith D. Shepherd, Andrew Sila, Robert A. MacMillan, Jorge Mendes de Jesus, Lulseged Tamene, Jérôme E. Tondoh

Published: June 25, 2015 • DOI: 10.1371/journal.pone.0125814

Abstract

80% of arable land in Africa has low soil fertility and suffers from physical soil problems. Additionally, significant amounts of nutrients are lost every year due to unsustainable soil management practices. This is partially the result of insufficient use of soil management knowledge. To help bridge the soil information gap in Africa, the Africa Soil Information Service (AfSIS) project was established in 2008. Over the period 2008–2014, the AfSIS project compiled two point data sets: the Africa Soil Profiles (legacy) database and the AfSIS Sentinel Site database. These data sets contain over 28 thousand sampling locations and represent the most comprehensive soil sample data sets of the African continent to date. Utilizing these point data sets in combination with a large number of covariates, we have generated a series of spatial predictions of soil properties relevant to the agricultural management—organic carbon, pH, sand, silt and clay fractions, bulk density, cation-exchange capacity, total nitrogen, exchangeable acidity, Al content and exchangeable bases (Ca, K, Mg, Na). We specifically

Predictions soil org. carbon (1km vs 250m)



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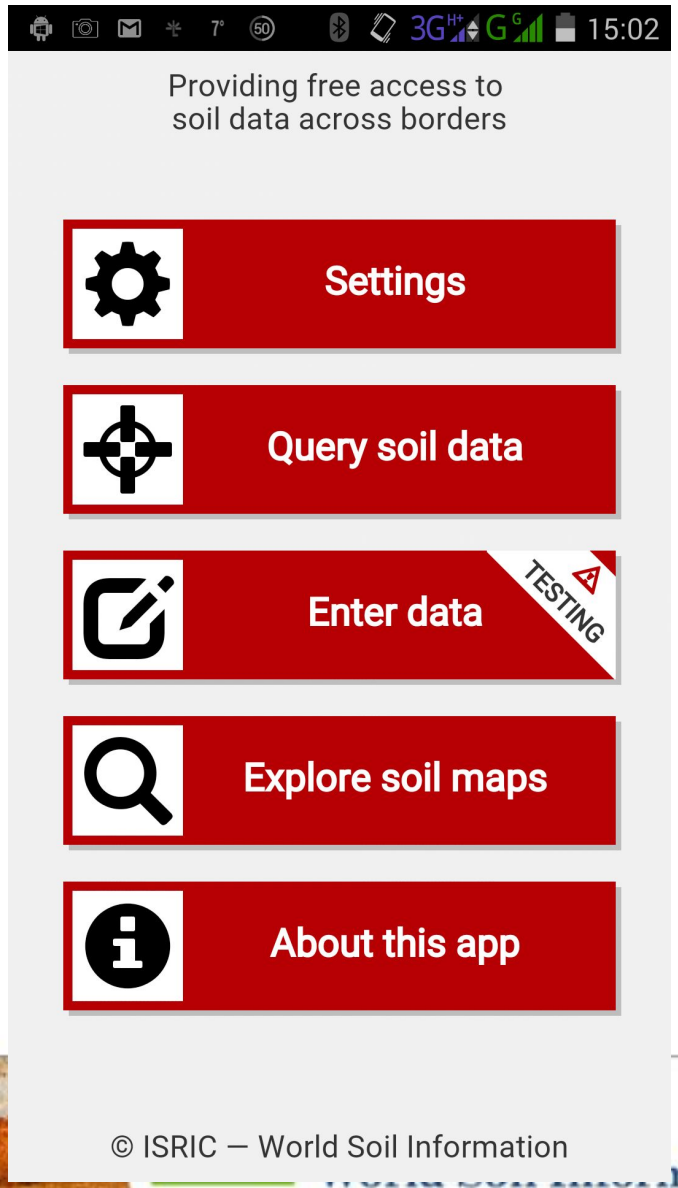
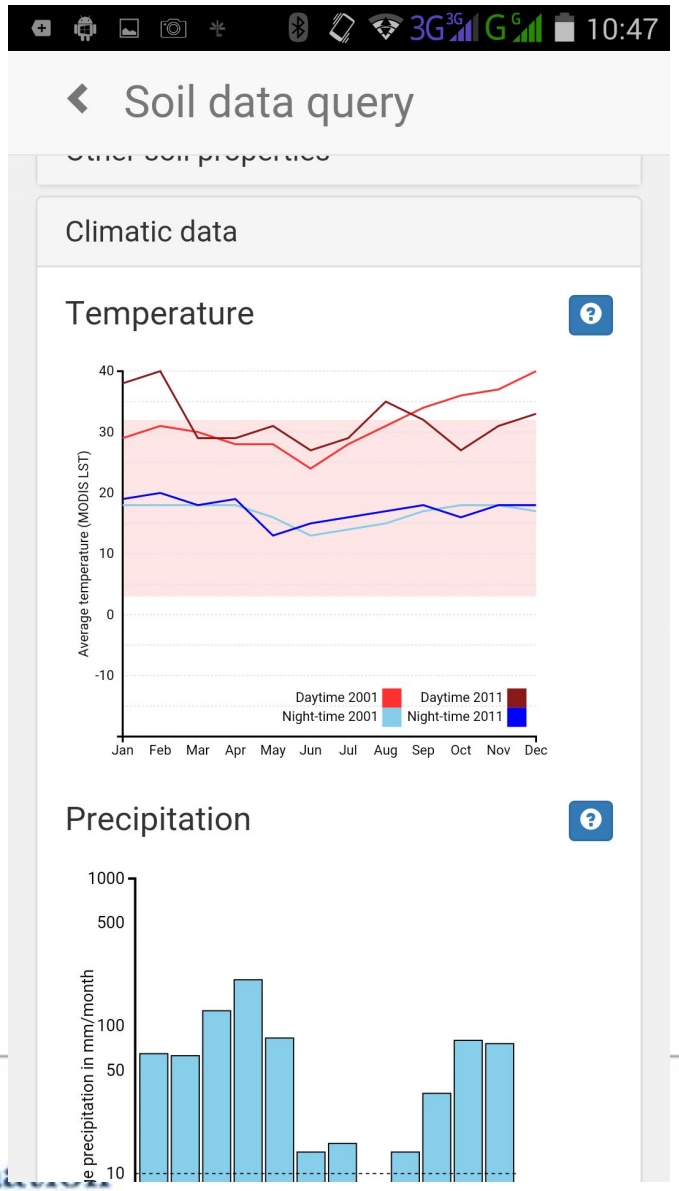
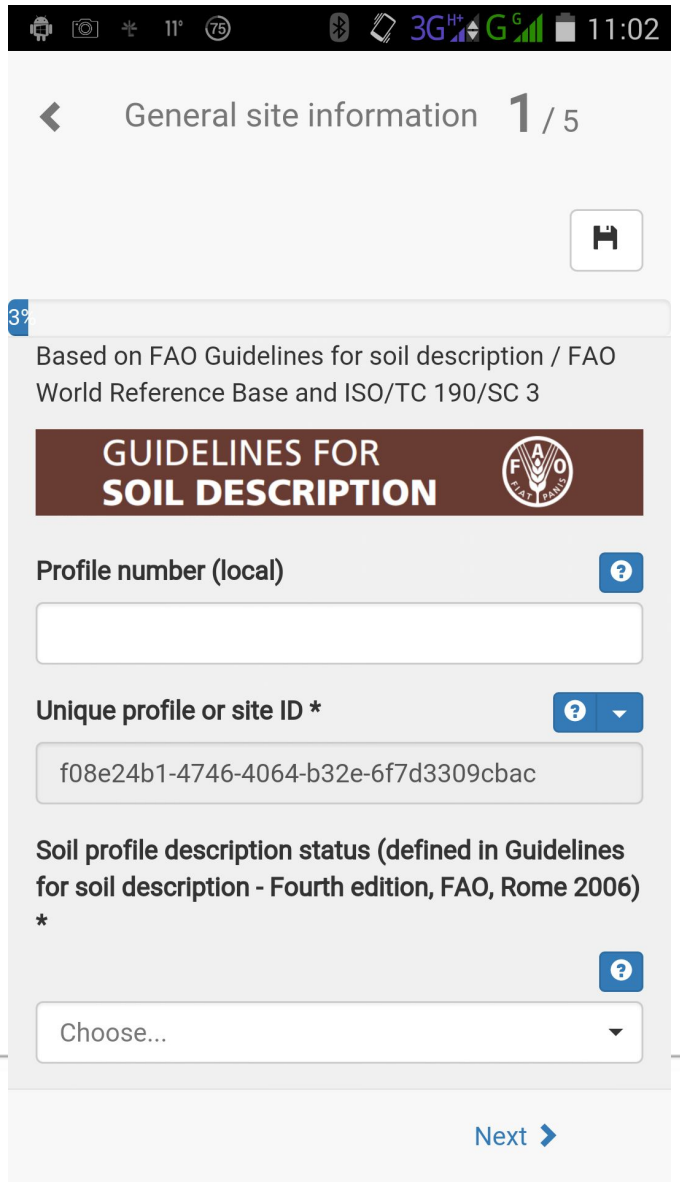
1 km (left) vs 250 m (right). Location: Arusha, Tanzania

SoilGrids → SoilInfo App







Soil Wiki

GBIF's vision: ***"A world in which biodiversity information is freely and universally available for science, society and a sustainable future."***

GSIF's vision: ***"... soil information ..."***

SoilGrids250m

Aspect	*SoilGrids1km*	*SoilGrids250m*
Spatial resolution	1000	250 (16 x bigger)
Input point data	ca 100,000 points	ca 130,000 with points also in Russian Federation, Artic/Antartic
Covariates	ca 70 unique	ca 150 (2 x more)
Prediction domain (soil mask)	excludes deserts, permanent ice	excludes only permanent ice
Spatial prediction methods	linear regression (no kriging)	machine learning (random forests, neural networks etc) / ensemble predictions
Artifacts and	country borders, artifacts and noise from MODIS products, artifacts in the geological map and HWSD	*reduced to minimum
Systematic bias	(over-smoothing) over-prediction of low value	*to be tested

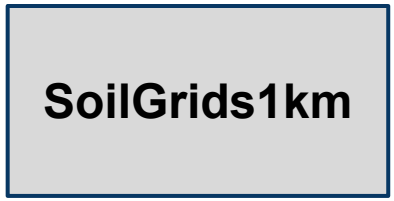
This is probably one of the biggest (statistical) soil mapping projects ever!

Visually

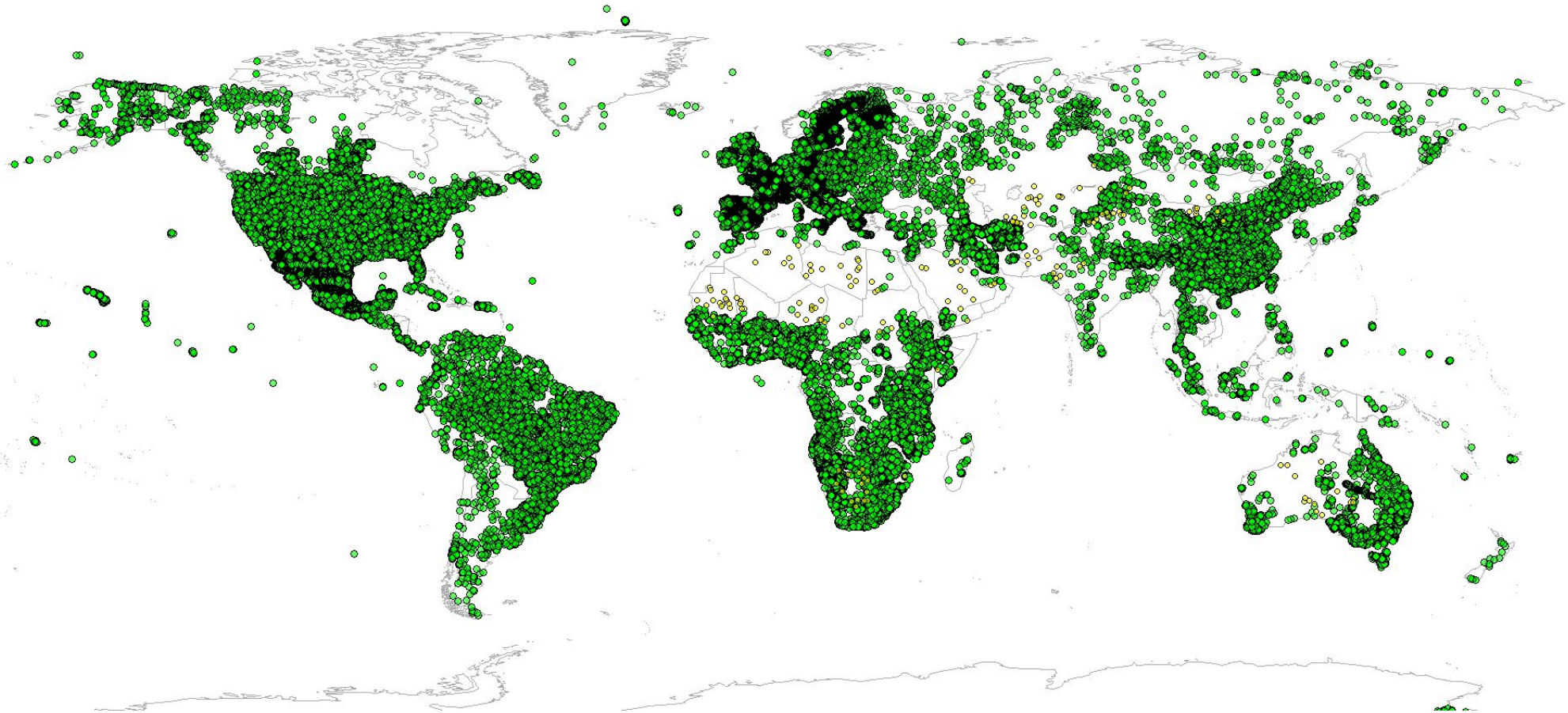
"BIG"
DAT
A

large

small



ca 150,000 points shown on this map



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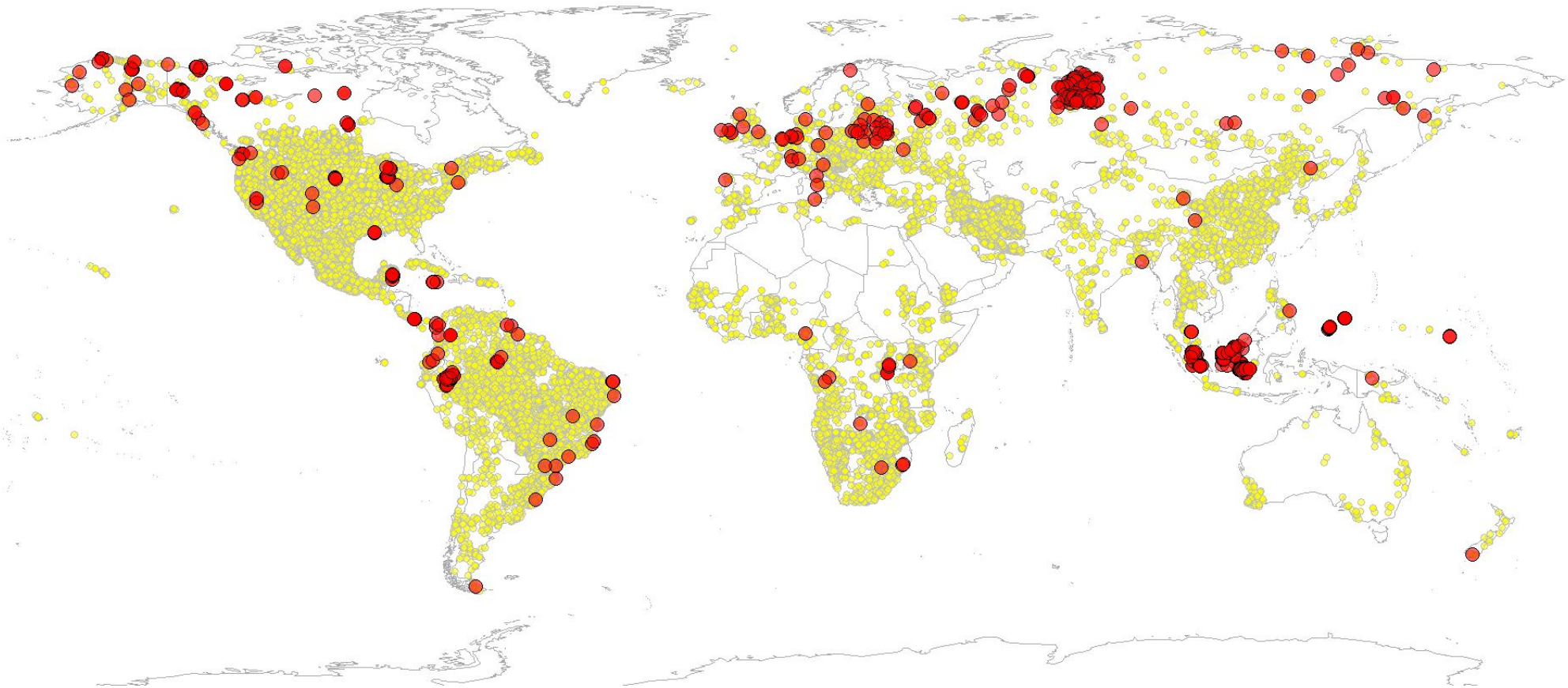
>850,000 measurements of soil organic carbon

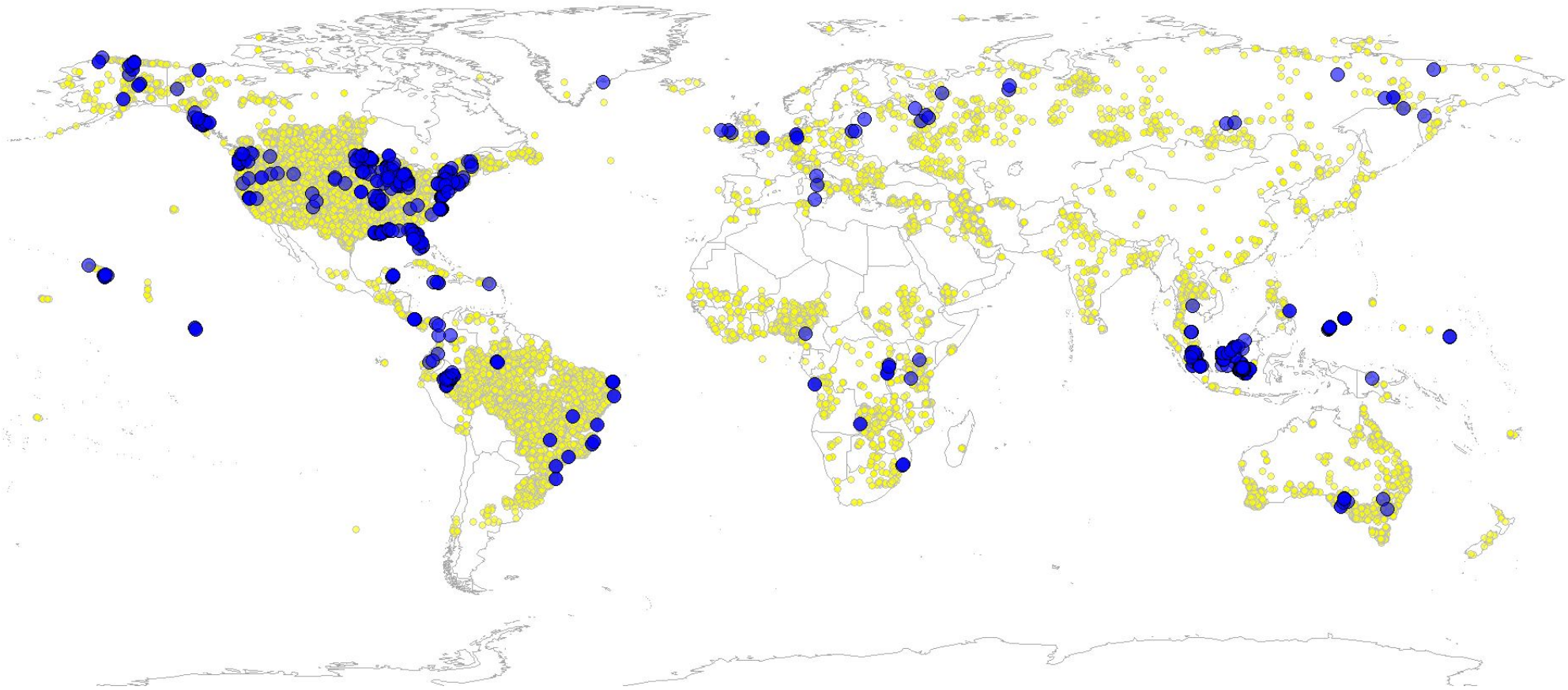
ca 45,000 points shown on this map



FAO World Reference Base

"Sapric.Histosols", "Hemic. Histosols", "Fibric.Histosols", "Cryic.Histosols", "Histic. Albeluvisols

ca 52,000 points shown on this map



USDA Soil Taxonomy

"Saprists",
"Hemists",
"Folists", "Fibrists"

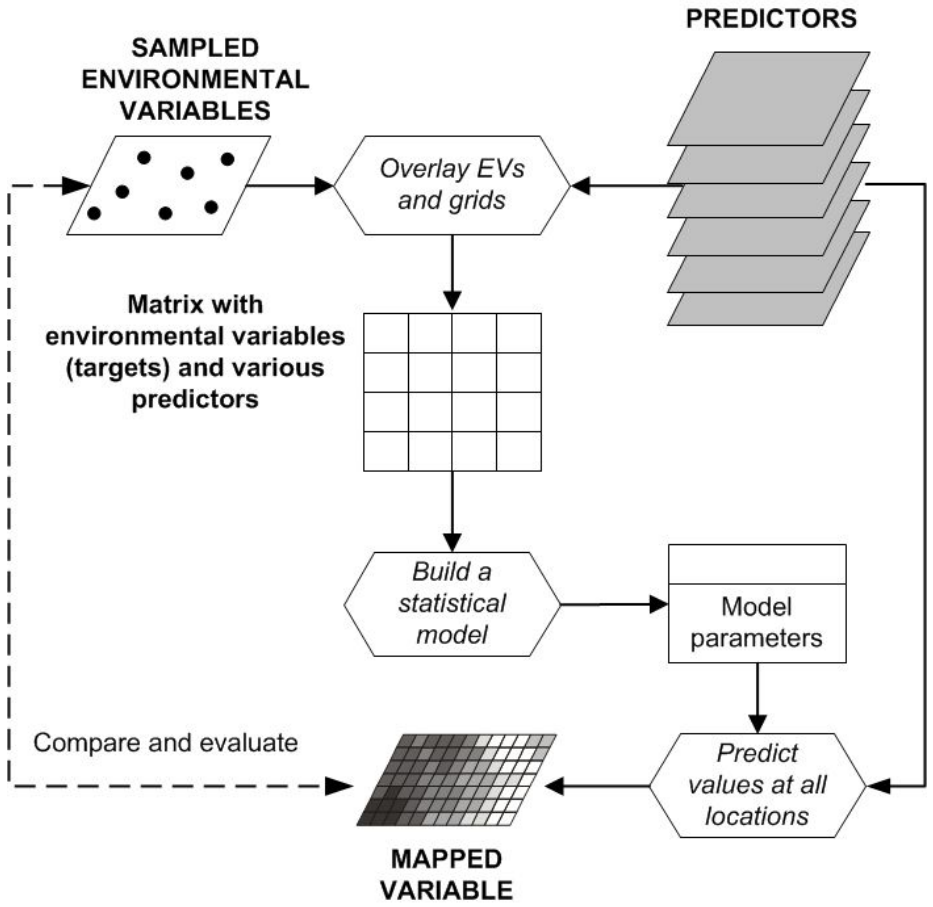
Soil_Taxonomy

File Edit View Insert Format Data Tools Add-ons Help Last edit was 2 days ago

	A	B	C	D	E
1	**WRB06**	**count**	**USDA_suborder**	**USDA_Group**	**USDA_Great_Group**
2	Umbric Albeluvisols Abruptic	80	aqualfs	haplic glossudalfs	Glossaqualfs
3	Greyic Phaeozems Albic	67	aquolls	typic endoaquolls	Endoaquolls
4	Voronic Chernozems Pachic	55	ustolls / udolls	#N/A	#N/A
5	Rustic Podzols	33	aquods	typic haplorthods	Epiaquods
6	Aluandic Andosols Dystric	30		#N/A	#N/A
7	Entic Podzols	30	aquods	typic haplorthods	Epiaquods
8	Haplic Cambisols Dystric	22		#N/A	Anthracambids
9	Haplic Cambisols Eutric	21		#N/A	Anthracambids
10	Rendzic Leptosols Eutric	19		#N/A	#N/A
11	Gleyic Albeluvisols Abruptic	17	aqualfs	haplic glossudalfs	Glossaqualfs
12	Haplic Albeluvisols Abruptic	17	aqualfs	haplic glossudalfs	Glossaqualfs
13	Haplic Kastanozems Chromic	17	xerolls	vitrandic haploxerolls	#N/A
14	Luvic Phaeozems Albic	17	albolls	typic argiudolls	Argialbolls
15	Haplic Gleysols Dystric	16	aquents	fluvaquentic endoaquepts	Endoaquents
16	Endogleyic Cambisols Dystric	14		#N/A	Anthracambids
17	Histic Albeluvisols Abruptic	13	aqualfs	haplic glossudalfs	Glossaqualfs
18	Vitric Cryosols Dystric	13	orthels	#N/A	Anhyorthels
19	Fibric Histosols Dystric	12	fibrists	#N/A	Cryofibrists
20	Luvic Stagnosols Dystric	12		#N/A	#N/A
21	Rubic Arenosols Eutric	12	psamments	typic udipsamments	Cryopsamments
22	Calcic Geysols Humic	11	aquents	fluvaquentic endoaquepts	Endoaquents
23	Gleyic Vertisols Eutric	11	aquerts	typic epiaquerts	Duraquerts
24	Haplic Cryosols Reductaquic	11	orthels	#N/A	Anhyorthels
25	Mollic Leptosols Eutric	11		#N/A	#N/A
26	Umbric Fluvisols Oxyaquic	11		#N/A	Haplanthrepts
27	Follic Gleysols Gelic	10	aquents	fluvaquentic endoaquepts	Endoaquents
28	Haplic Cryosols Dystric	10		#N/A	Anhyorthels
29	Endosalic Kastanozems Sodic	9		vitrandic haploxerolls	#N/A
30	Histic Cryosols Reductaquic	9	orthels	#N/A	Anhyorthels
31	Endogleyic Planosols Albic	8		typic albaqualfs	#N/A
32	Haplic Arenosols Eutric	8	psamments	typic udipsamments	Cryopsamments
33	Haplic Podzols	8	aquods	typic haplorthods	Epiaquods
34	Histic Andosols Dystric	8		#N/A	#N/A
35	Luvic Chernozems Sodic	8		#N/A	#N/A

cleanup_China_WRB | SPADE_FAO_90 | cleanup_SU_SYM90 | cleanup_OFRA | FAO_90_names | cleanup_MX_FAO

General spatial prediction workflow (data-driven)



Regression matrix = 154 covariate layers x 150,000 sites (soil profiles / samples)

Model fitting = Random Forest, neural nets / Deep learning

h2o software

Documentation | Discussion

Index / h2o

h2o

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H2O R Interface

Run H2O via its REST API from within R.

Author(s):
Anqi Fu, Spencer Aiello, Ariel Rao, Tom Kraljevic and Petr Maj, with contributions from the 0xdata team

Version:
2.8.1.1

License:
Apache License (== 2.0)

Maintainer:
Tom Kraljevic <tomk@0xdata.com>

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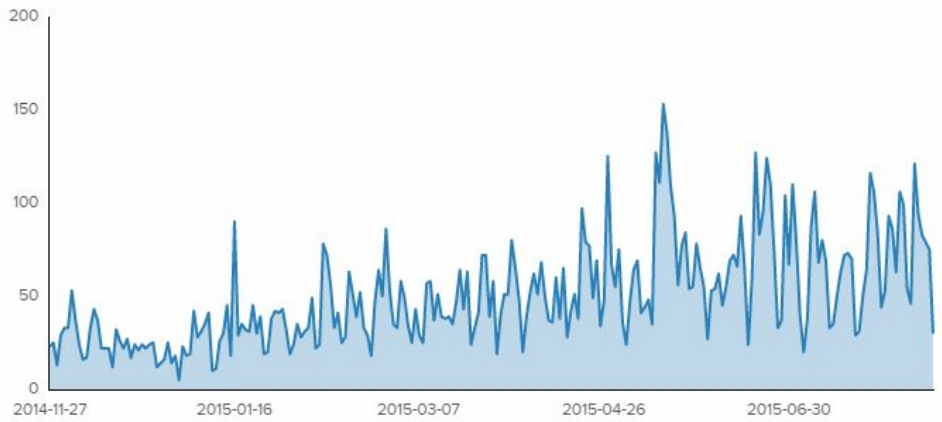


H2O

H_2O

Original author(s)	0xdata
Developer(s)	H2O.ai
Stable release	Slater (Version 3.2.0.5) / September 24, 2015; 2 months ago
Development status	Active
Written in	H2O (written in Java, Python, and *R*)[1][2][3]
Operating system	Linux, Mac OS, and Microsoft Windows
Platform	Apache Hadoop Distributed File System; Amazon EC2, Google Compute Engine, and Microsoft Azure.
Available in	English
Type	big data analytics, machine learning, statistical learning theory[4]
License	Open source
Alexa rank	606,809[5]
Website	0xdata.com

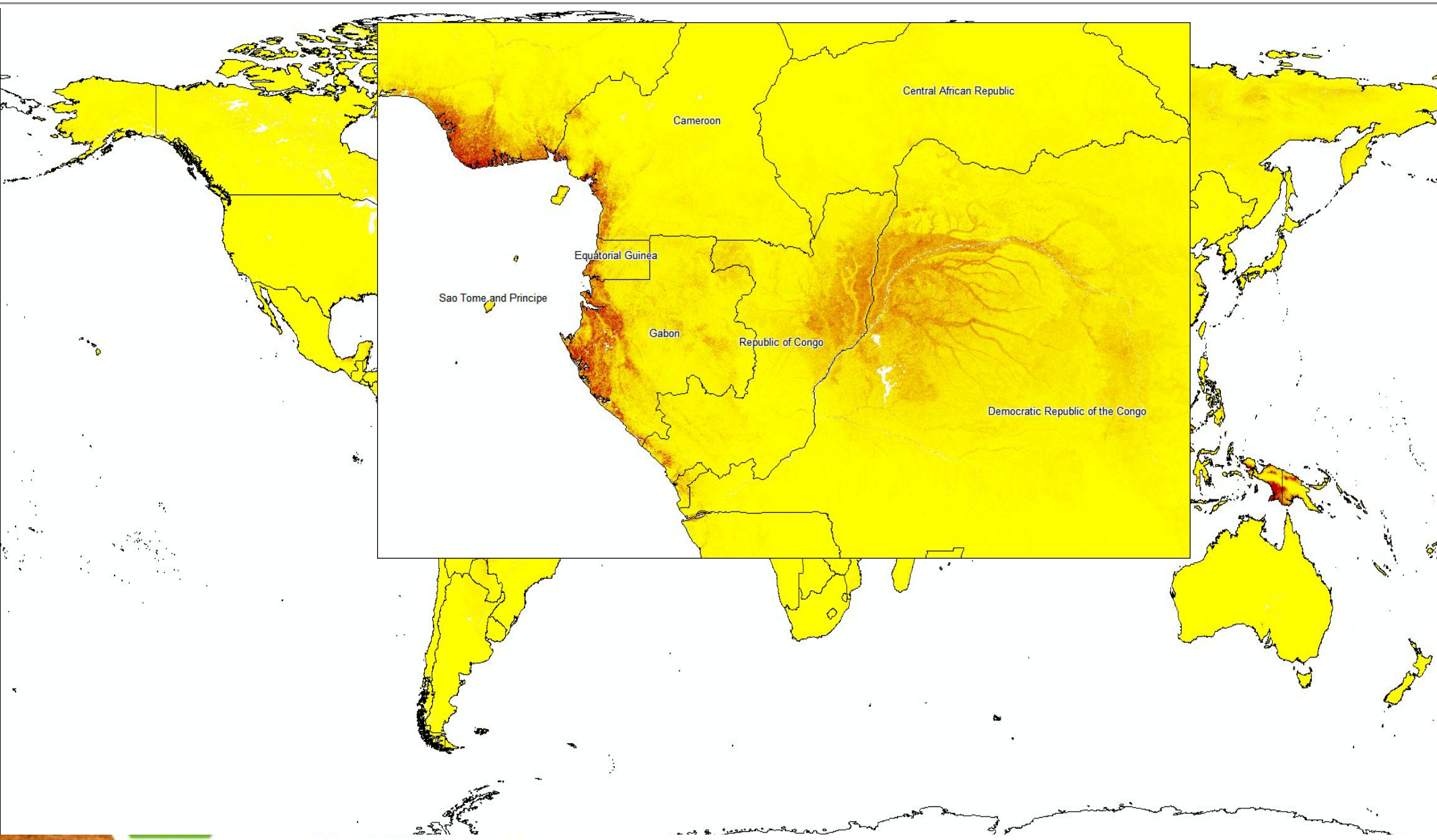
Results

Model testing

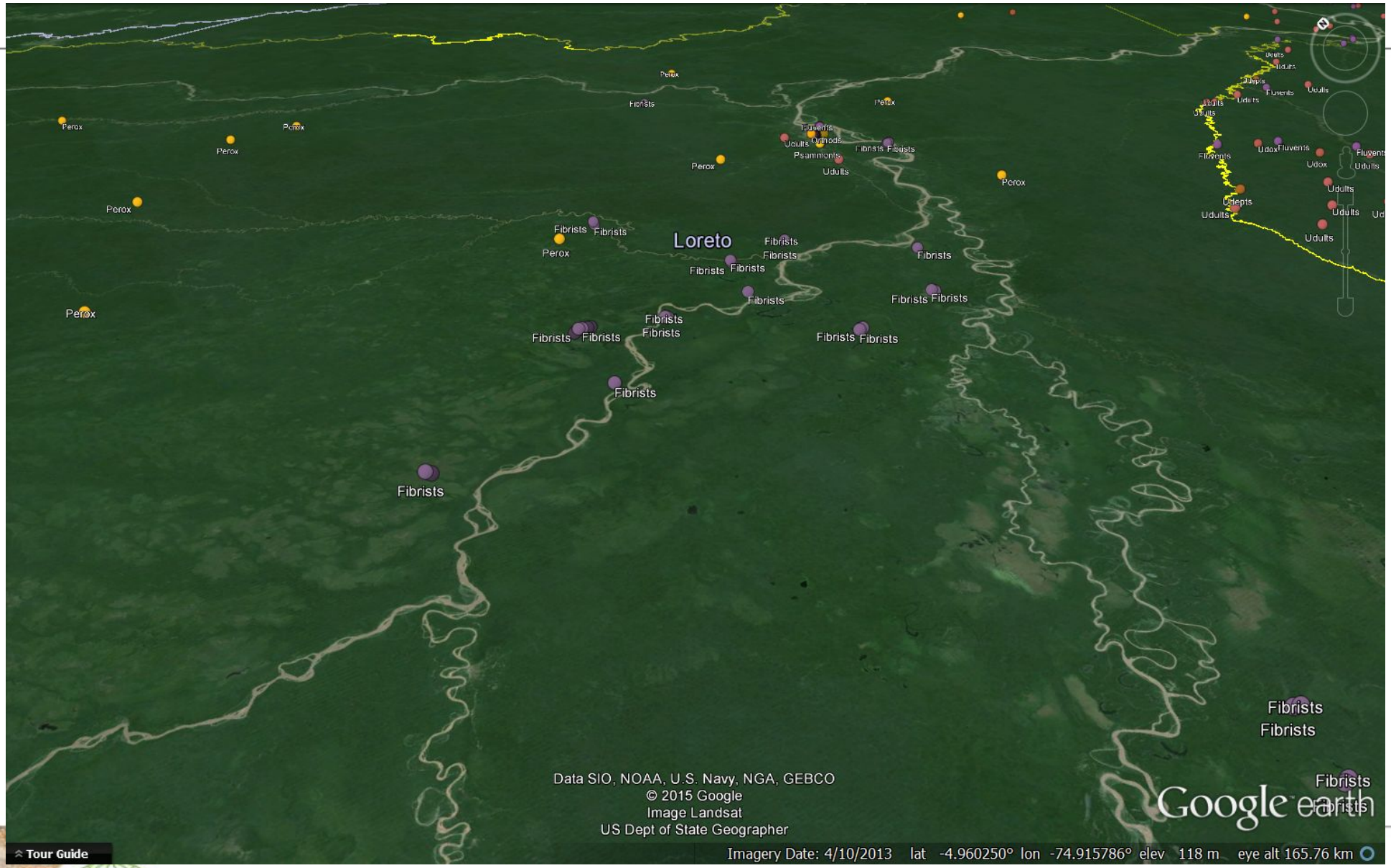
- FAO / USDA Soil taxonomy classes:
  - Estimated Cohen Kappa (weighted): 29–40%
  - Map purity: 30–40%

- R-square for soil organic carbon, pH, soil textures, coarse fragments, bulk density (Random Forest models): 63–82%

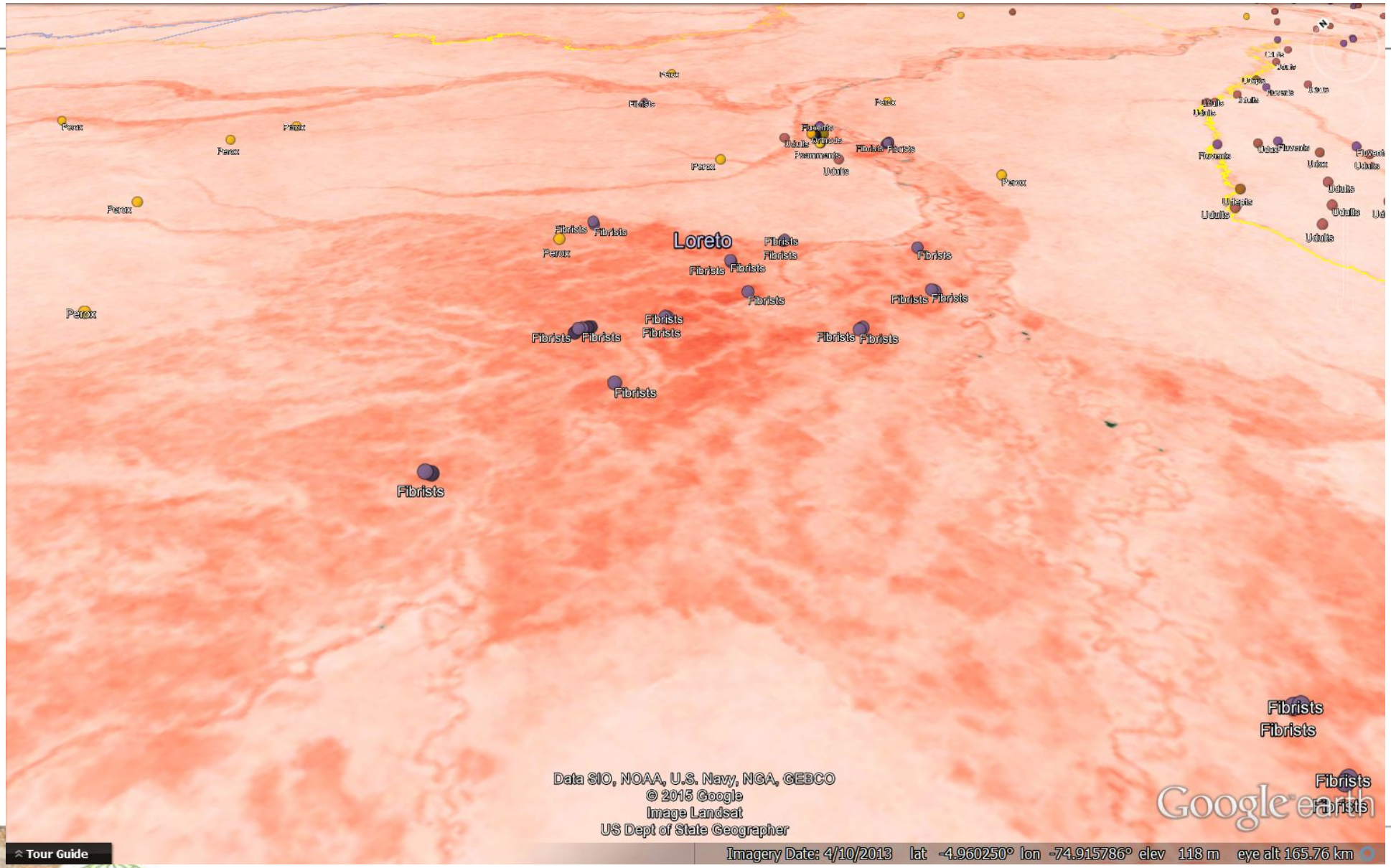
Fibrists


Central African Republic
Cameroon
Equatorial Guinea
Sao Tome and Principe
Gabon
Republic of Congo
Democratic Republic of the Congo

Fibrists


Loreto
Perox
Fibrists
Udults
Fluvents
Udepts
Udox
Psamments
Orthods
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2015 Google
Image Landsat
US Dept of State Geographer
Google earth
Tour Guide
Imagery Date: 4/10/2013 lat -4.960250° lon -74.915786° elev 118 m eye alt 165.76 km

Fibrists


Loreto
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Perox
Udults
Fluvents
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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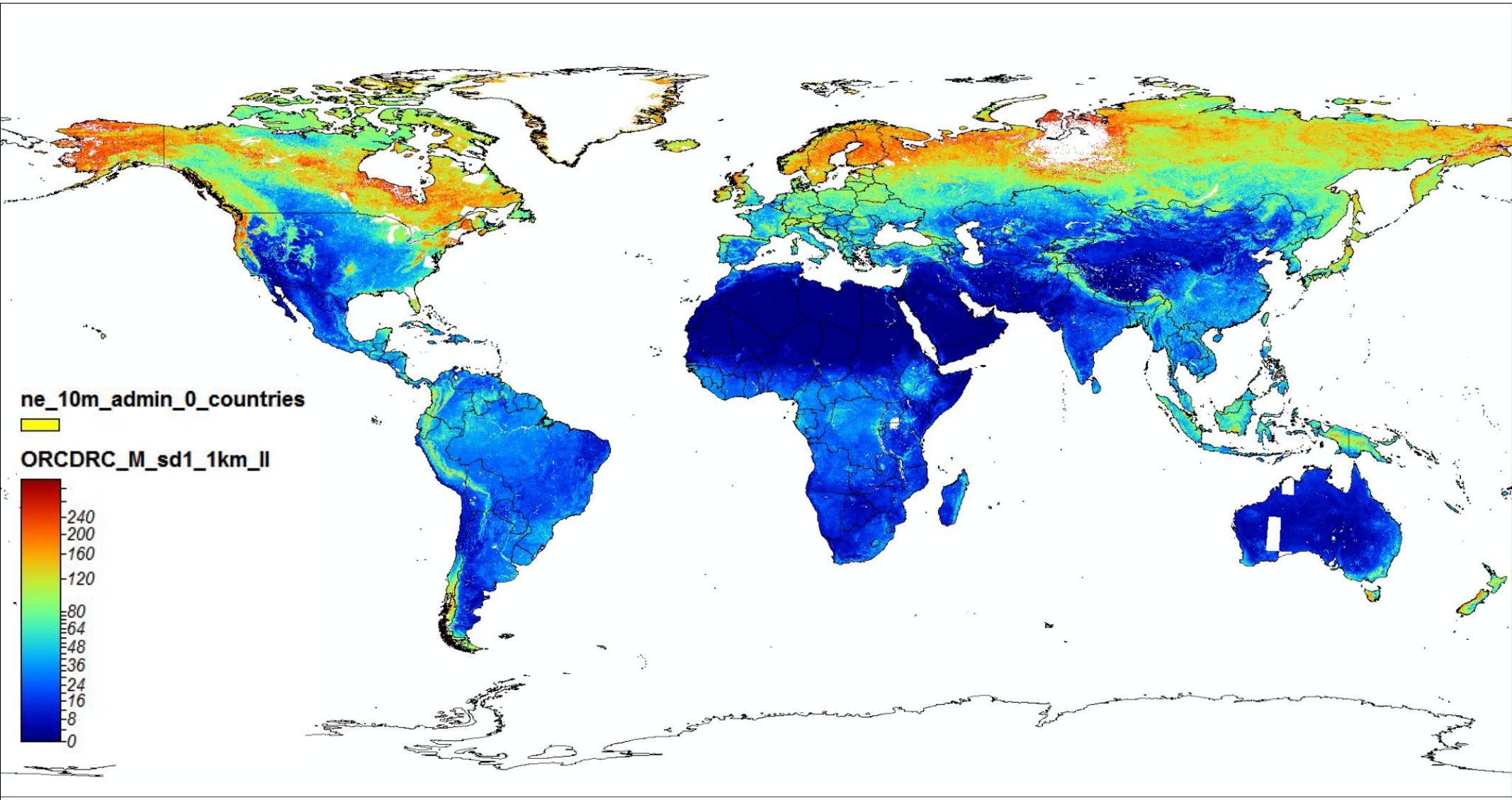
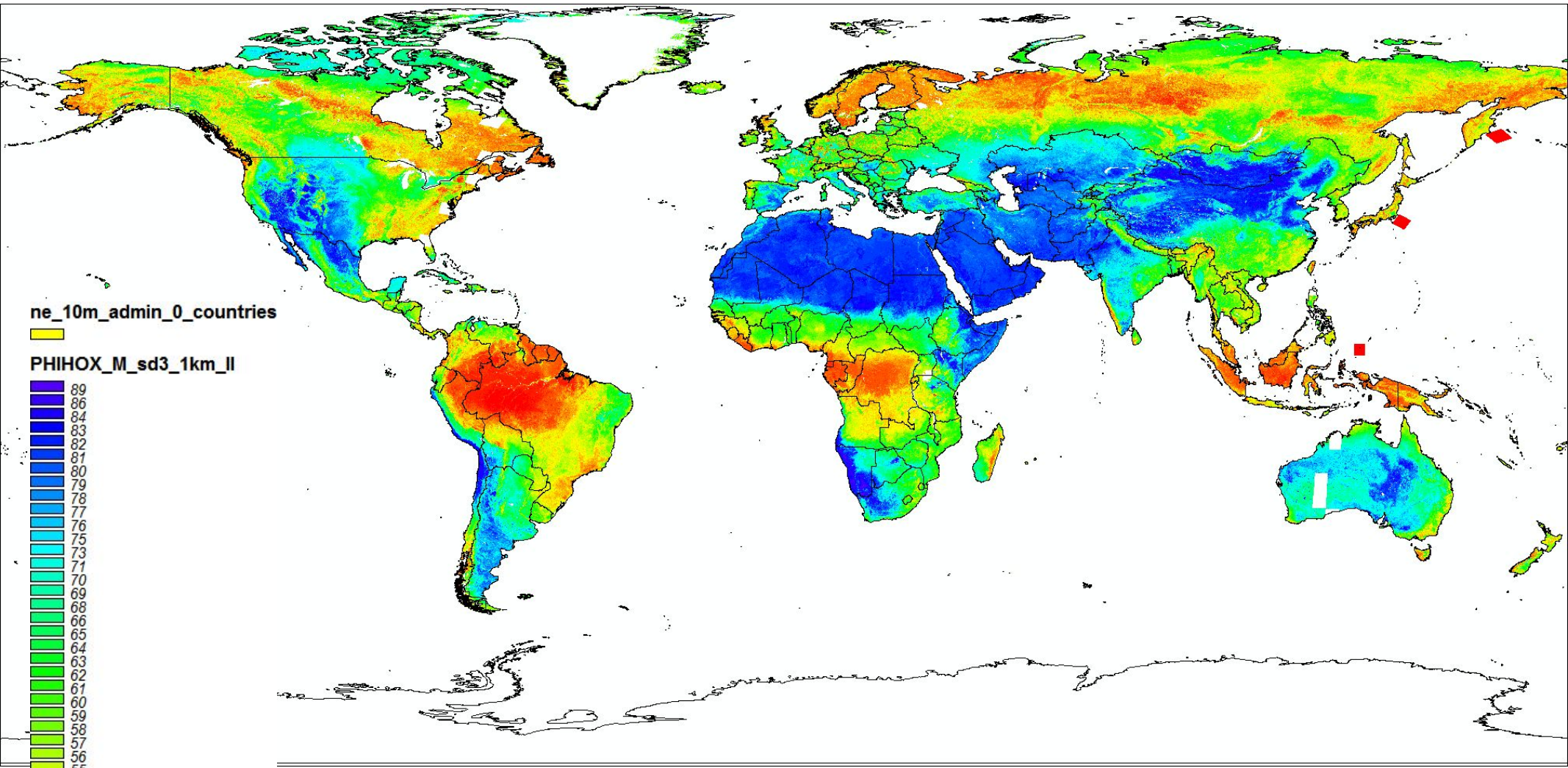
Image Landsat
US Dept of State Geographer
Google earth
Tour Guide
Imagery Date: 4/10/2013 lat -4.960250° lon -74.915786° elev 118 m eye alt 165.76 km

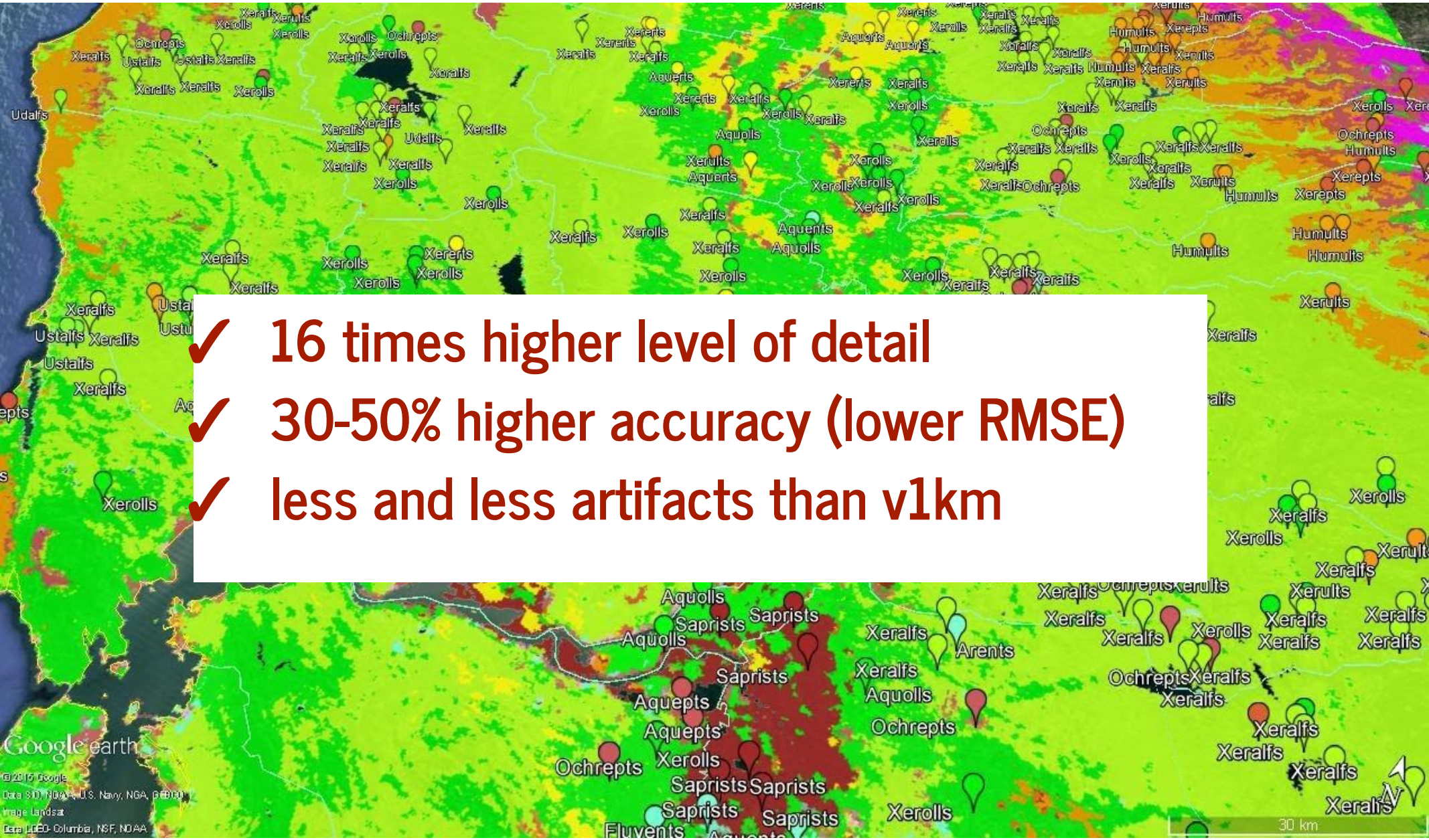
Soil organic carbon



Soil pH (5–15 cm)



World Soil Information



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Conclusions

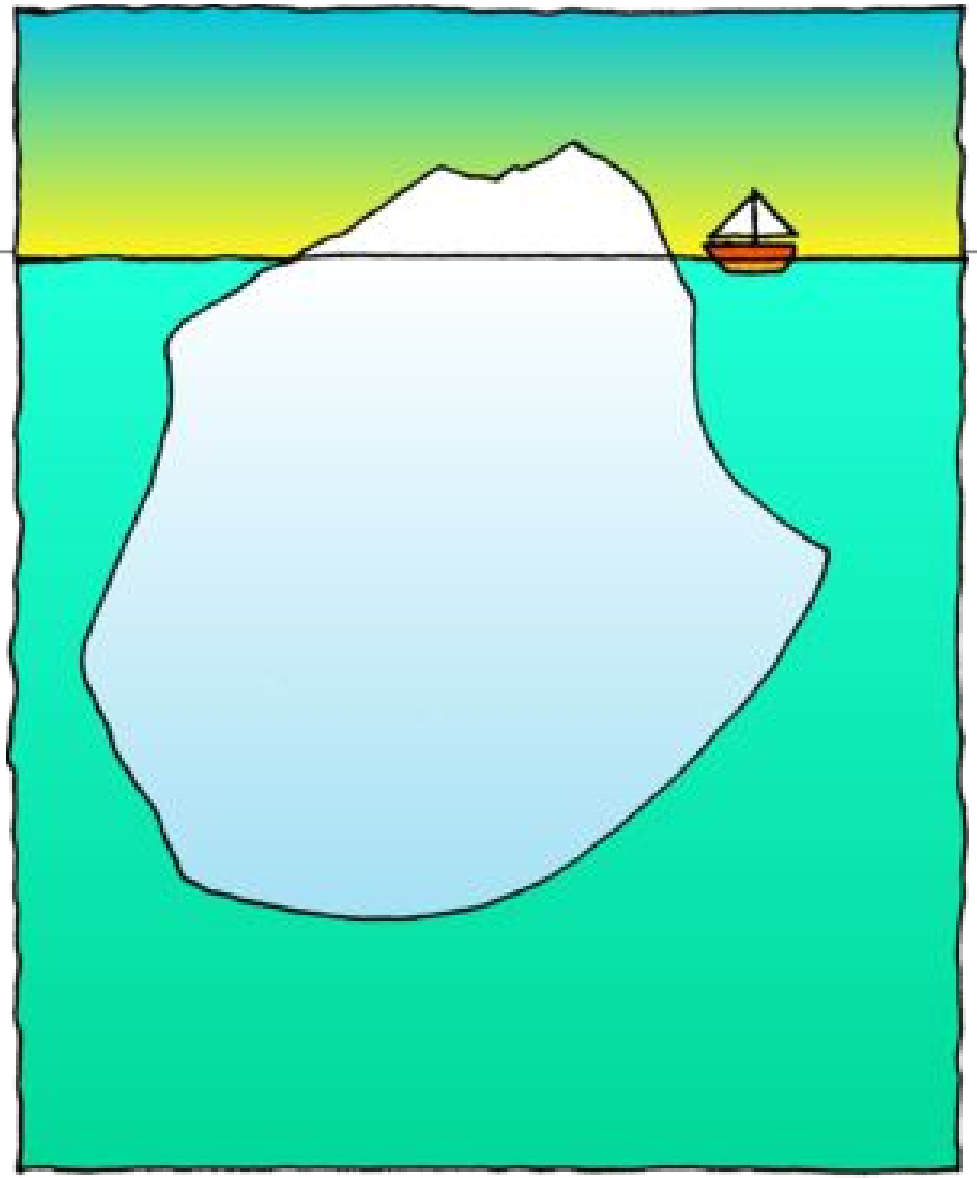
1. (Non-linear) machine learning algorithms show predictive potential for automated soil mapping

2. There is a potential in soil mapping automation and in using global soil data models (to fill-in the data gaps / transfer knowledge)

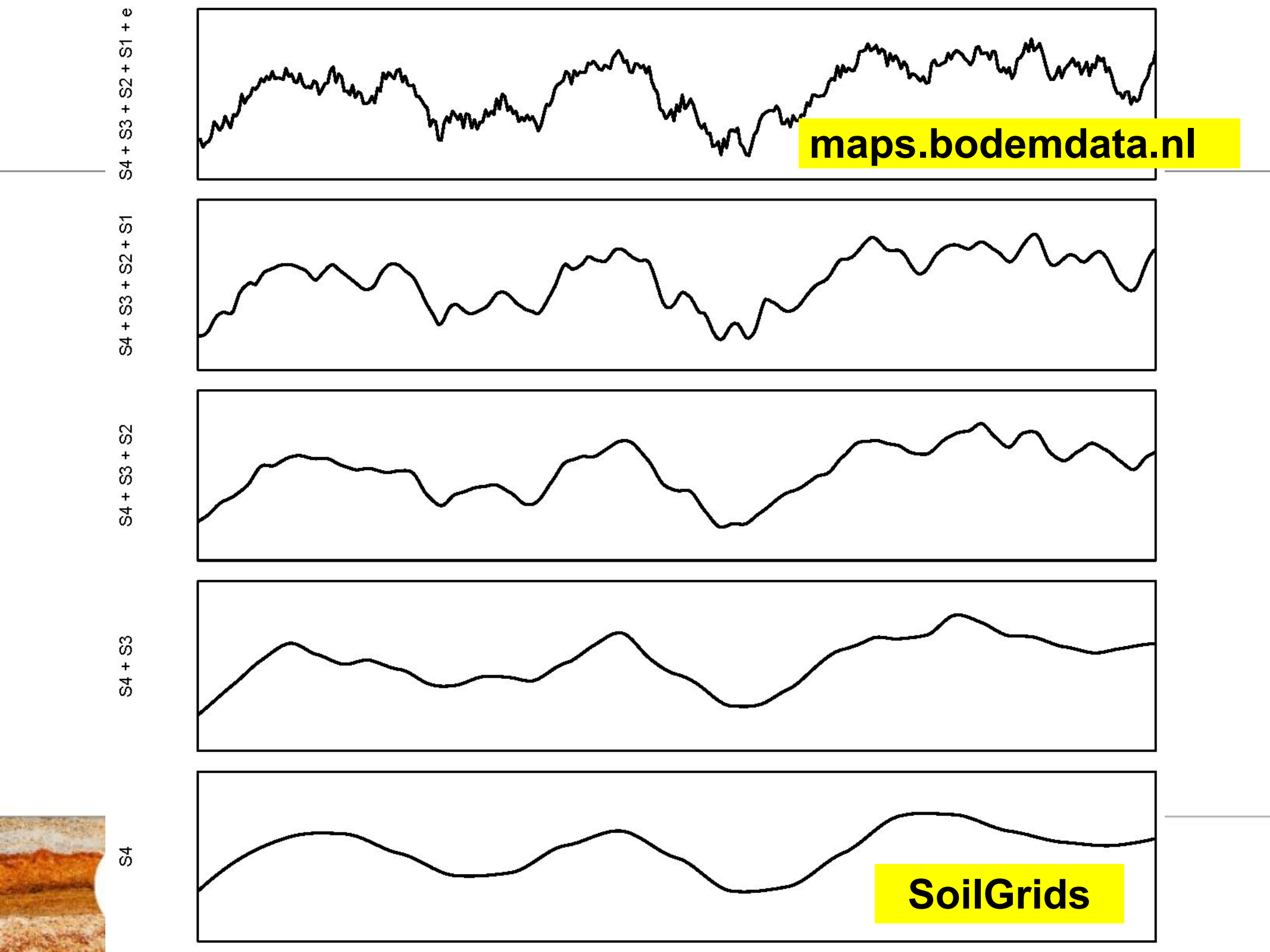
3. SoilGrids could be used to generate even hundreds of soil properties (automation is possible)!

Get ready for the Soil Data Revolution!

SoilGrids250m



God's Word is like an iceberg-
there is more truth unseen than seen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maps.bodemdata.nl
SoilGrids

NATURE | COMMENT

Agricultural policy: Govern our soils

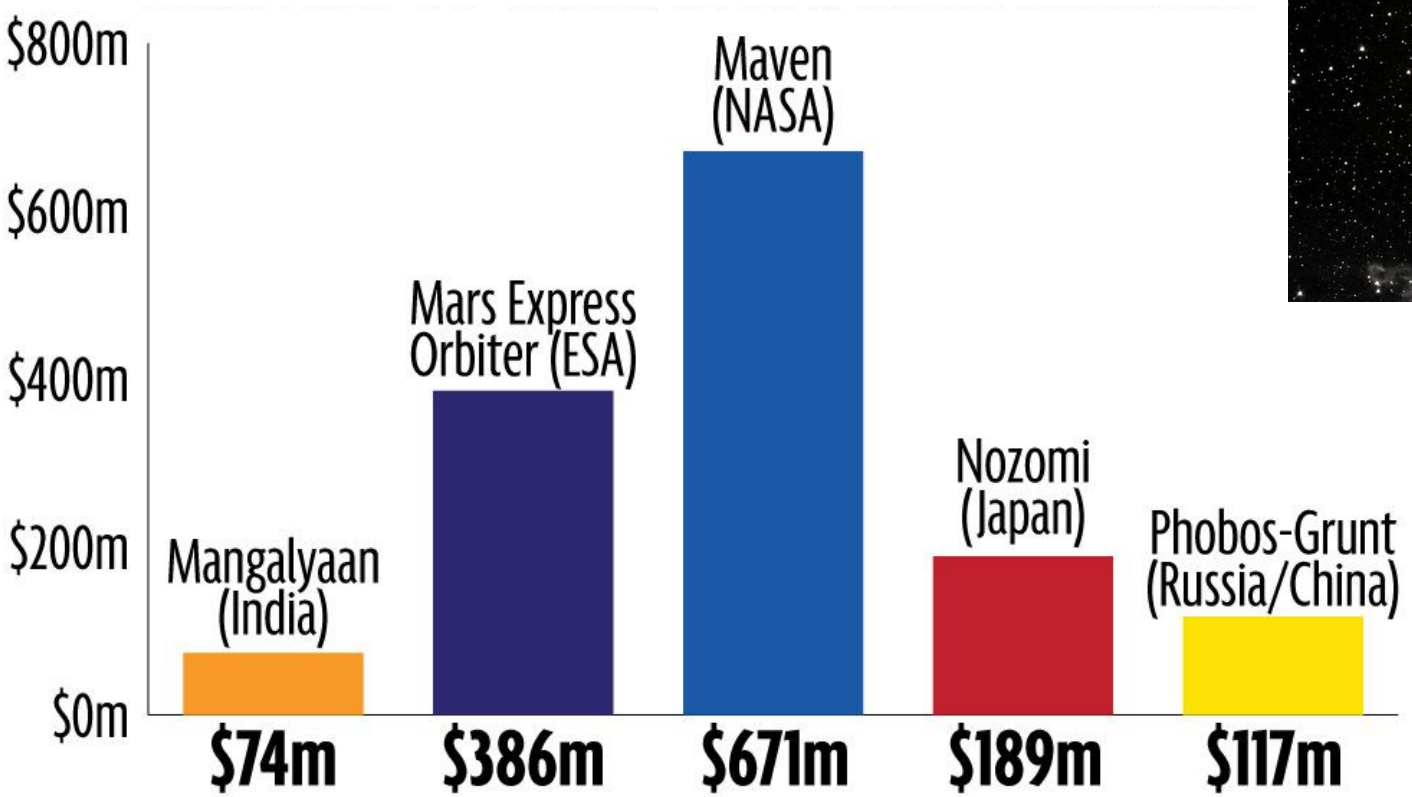
Luca Montanarella

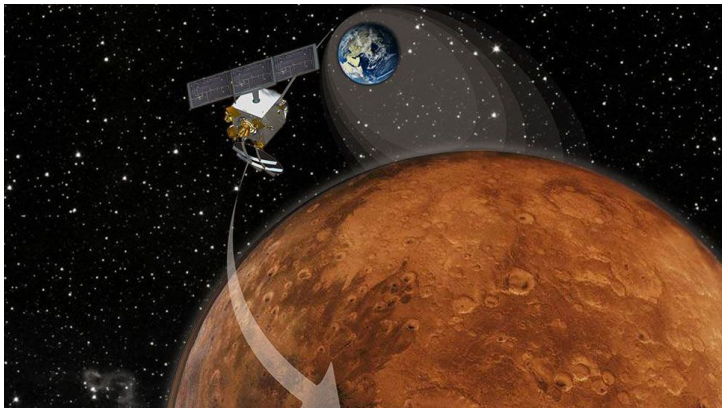
23 November 2015

Luca Montanarella calls for a voluntary international agreement to protect the ground beneath our feet from erosion and degradation.

Subject terms: Agriculture · Policy

We know more about soils of Mars…





"... than we know about the soils of Earth" → we need to change this!

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