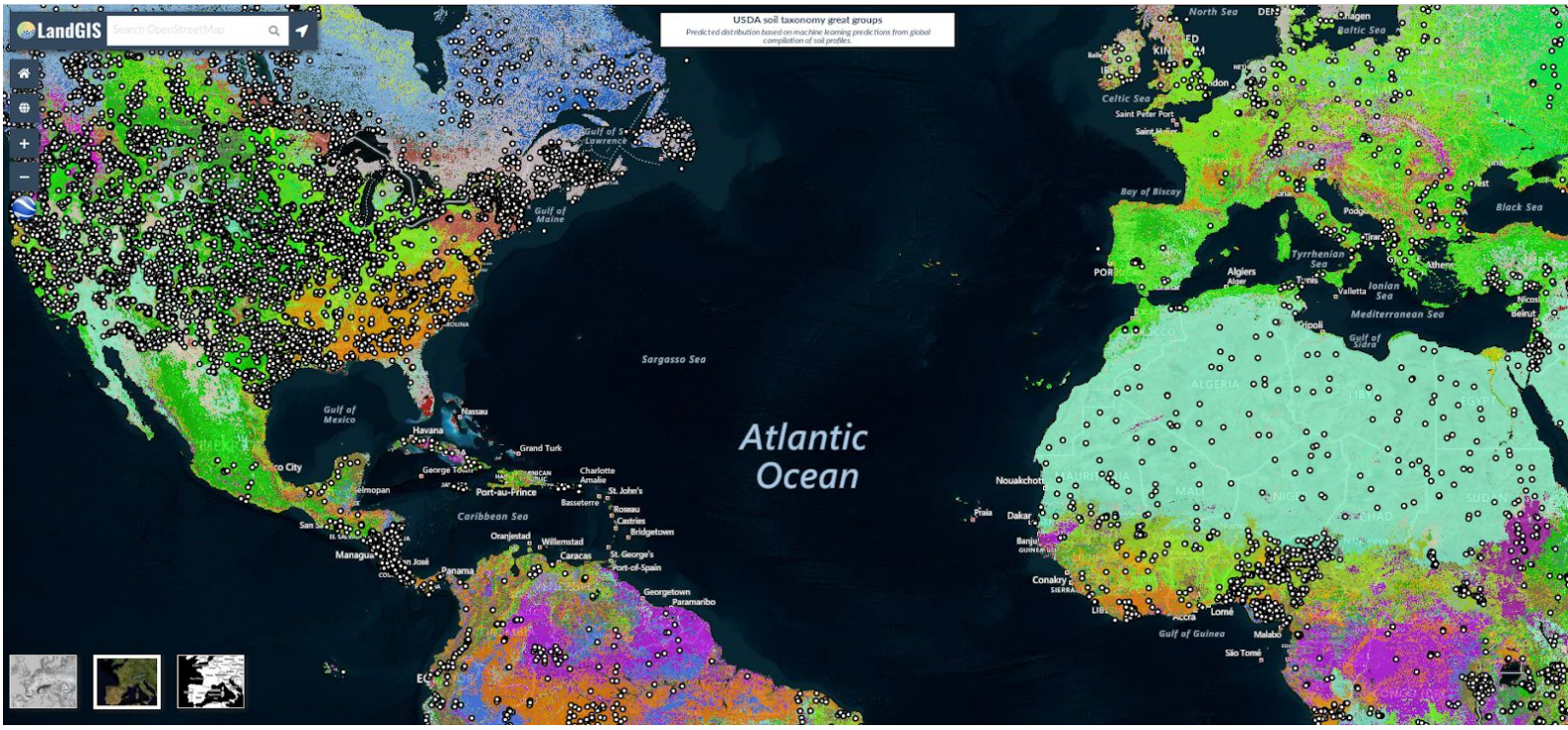

LandGIS: global soil and vegetation mapping using legacy field observations and state-of-the-art Machine Learning

OpenGeoHUB
Connect • Create • Share • Repeat

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Introduction

OpenGeoHub foundation

OpenGeoHub foundation is a not-for-profit research foundation headquartered in Wageningen, the Netherlands (https://opengeohub.org). We engage in the development of Open Geodata, Open Source Software and platforms for creation, publication and sharing of Geoscientific Data. OpenGeoHub runs training courses, creates training materials, contributes to the development of new scientific methods and standards and organizes and hosts conferences and workshops in the areas of geoprocessing, open source GIS, machine learning, Big Data and application specific domains such as geomorphometry and predictive soil and vegetation mapping.

We produce and serve global geodata because these are things that we are very good at doing. However, we recognize that the value of any data is in its beneficial and profitable use. So, it is really important to us that our data get widely used to do good things and that we make every possible effort to facilitate and encourage this beneficial use. Our core philosophy is outlined in the following documents (see also our Medium article on LandGIS):

- Hengl T, Wheeler I, MacMillan RA. 2018. **A brief introduction to Open Data, Open Source Software and Collective Intelligence for environmental data creators and users**. PeerJ Preprints 6:e27127v2 https://doi.org/10.7287/peerj.preprints.27127v2
- Hengl, T., MacMillan, R.A., (2019). **Predictive Soil Mapping with R**. OpenGeoHub foundation, Wageningen, the Netherlands, 370 pages, www.soilmapper.org, ISBN: 978-0-359-30635-0. http://soilmapper.org

Together, we have contributed to (a) development, application and testing of improved spatial prediction methods, (b) production and publication of new global environmental datasets using these methods, (c) reprocessing and extending the useful life of orphaned or underused global geoenvironmental data, (d) awareness-raising and usage for soil map generation, and (e) training a new generation of leaders in environmental data science (Fig. 1).

Fig 1: OpenGeoHub Summer School, Prague 19–25 August 2018.

LandGIS

In 2018 the Foundation released a web mapping system called **"LandGIS"** (https://landgis.opengeohub.org) which is envisaged as *"an OpenStreetMap-type system"* for land-related environmental data (Fig. 2). The system hosts global, moderate to fine spatial resolution data (250m to 1km), and is intended for eventual production and provision of farm-scale data and beyond. It also comes with a basic API (https://landgisapi.opengeohub.org) that already allows OpenGeoHub to serve business and developers. LandGIS was produced jointly with the help of EnvirometriX Ltd (https://envirometrix.net; data sets / spatial prediction framework) and GILab Ltd (http://www.lab4gi.com; web-mapping services and client development and REST API functionality).

LandGIS provides access to new and existing data on **soil properties/classes** (doi: 10.5281/zenodo.1476844), **relief** (doi: 10.5281/zenodo.1447209), **geology, land cover/use/degradation** (doi: 10.5281/zenodo.1475449), **climate** (doi: 10.5281/zenodo.1420114), **current and potential vegetation** (doi: 10.5281/zenodo.1450336, doi: 10.7717/peerj.5457).

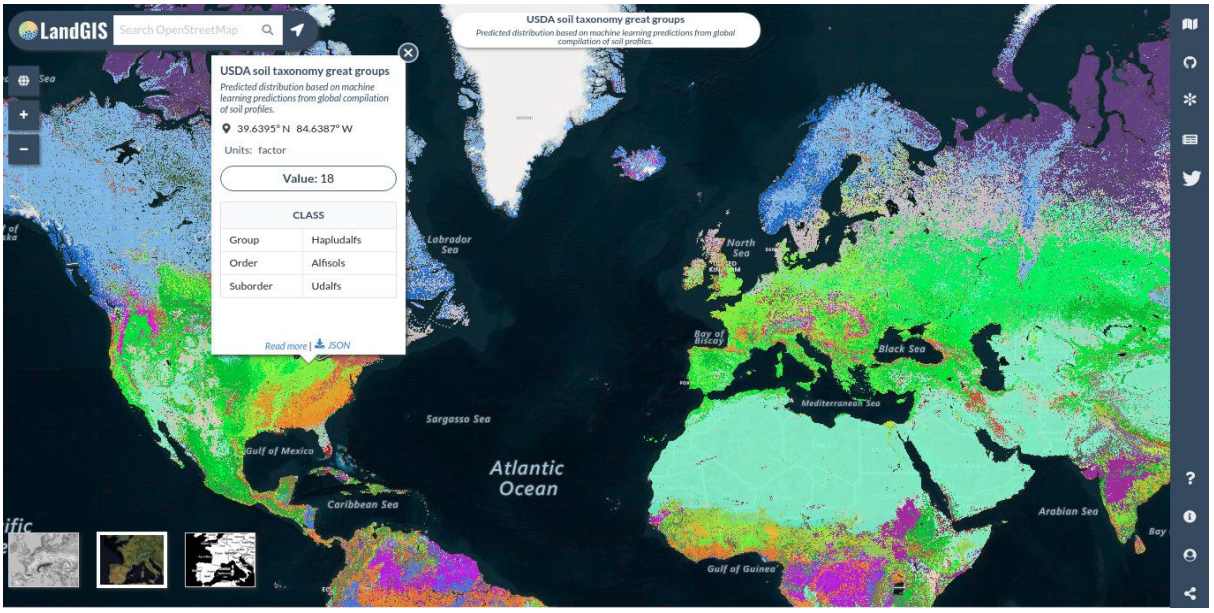

Fig. 2: LandGIS interface showing predicted global distribution of USDA great groups. Data available for download at doi:10.5281/zenodo.1476844

It also provides an easy user interface for visualization of, and access to, spatial and spatiotemporal land information in 2D and 3D. LandGIS was created, populated and launched over a period of less than 6 months using in-house seed-funding. With LandGIS we combine the power of Machine Learning for global spatial modeling using Open Source software with readily available open global geodata to produce seamless global maps of environmental dynamics and ecosystem services.

Current LandGIS functionality

- Access and visualization of dynamic information e.g. about land cover change (1992–2015),
- Access to all data layers via OGC standards WMS, WCS and similar (https://maps.opengeohub.org),
- Provision of REST API access to all gridded geodata e.g. values per point (https://landgisapi.opengeohub.org),
- URL based geo-bookmarking tool to share user defined 'views' to facilitate discussion of issues of land degradation, restoration potential and similar,
- Provision for others to contribute and share new layers via the platform (web-hosting),
- Regularly updated maps so that accuracy and usability improve continuously.

What is already groundbreaking about LandGIS?

- We have demonstrated that combining information on relief, vegetation and land cover dynamics, climate and soil, produces **a complete and consistent system that can deliver harmonized, 3-dimensional soil data across borders**.
- We have demonstrated that large amount of value-added data can be produced using Open Source software, and releasing the code with data could well be the basis of trust in data. Both our methods and their outputs are made **freely available under Open Source / Open Data licenses**.
- Using state-of-the-art machine learning we **improved the accuracy of soil property/class maps** for the most detailed soil-type and soil property maps of our world currently available.
- We incorporated all maps we have produced (about 4Tb) into **an open data service** using **100% Open Source** software solutions. As such it can be used and extended without restriction.
- By enabling open use of soil, land cover, vegetation and climate data, we are connecting thousands of researchers, specialists and land owners. LandGIS dreams to become the de-facto international reference for environmental data.

Our Motivation: why do we do what we do?

We believe that the importance and value of soils have been underestimated for centuries. Recent research indicates that soil is home to the majority of living organisms and that many important ecosystem interactions occur in the soil[1]. Soil is widely acknowledged as one of the key components in addressing climate change[2,3] and in achieving food security[4].

[1] https://dx.doi.org/10.1038/455724a
[2] https://www.greenbiz.com/article/soil-becomes-fertile-ground-climate-action
[3] https://www.nature.com/articles/d41586-018-07587-4
[4] https://www.nature.com/articles/d41586-017-09010-w

Soils are also far more fragile than generally recognized: **in the last 150 years, half of the topsoil on the planet has been lost due to erosion, compaction, desertification, acidification, and loss of soil organic carbon**[5]. It takes an order of magnitude longer to create 1m of soil than to regrow a forest[6]. Some reports estimate **only 60 years of viable farming remains if soil degradation continues at its current pace**[7]. Currently very little is known about soil degradation trends and **global high resolution soil maps are needed urgently**[8].

We further believe that the key to tackling many of these challenges is in making the highest quality decision-ready, actionable data available without restrictions. We are ambitious and enthusiastic about contributing to a revolution in how data about soil, land and the environment in general is produced, disseminated and used globally. We have always imagined OpenGeoHub as a vehicle for reducing barriers to both the production and the use of global geodata.

On the production side, we want to accelerate and improve the production of soil and environmental data globally. We provide access to comprehensive global data sets as well as to a platform and tools for creating geodata. We do this so that any motivated and competent individual, agency or institution can participate fully and effectively in the production of new global geodata. We hope that our initial worked examples will convince people that they too can produce useful and important contributions to global geodata and that they will consequently decide to make use of our base data and our modelling platform to create new geodata to contribute for free global use. The larger and more diverse we can make the pool of contributors to the production of new data, the more diverse and useful the resulting offerings of free geodata are likely to be. We can't know about all possible types of useful data, so we look to others to help create the most diverse and most useful collection possible. We do anticipate that initial products will result in recognition of a critical need to collect new field observations and measurements to support the production, by ourselves and others, of higher quality, next generation soil and environmental information products at global to local scales. In particular, we envisage increased production of 3D space-time models to track changes in time and space.

We also focus on reducing or removing barriers to use. We want to disrupt current models that restrict and limit the distribution and use of soil and land information. One way we reduce barriers is by providing a world class platform where all manner of relevant environmental data can be hosted and made available using ***FAIR*** data principles[9]. This means that we make all our data ***Findable***, ***Accessible***, ***Interoperable*** and ***Reusable***. The LandGIS application provides a state of the art platform where users can easily ***Find*** global geodata. Using LandGIS they can rapidly and intuitively discover, visualize, review and assess huge volumes of relevant global geodata. We make our geodata fully ***Accessible*** by making it Free and Open. Open data and content can be freely used, modified, and shared by anyone for any purpose. We adopt Open licensing, provide Open access and use Open data formats. We make our data ***Interoperable*** by avoiding the use of any proprietary data formats that can only be accessed and opened using commercial software. We publish our data using widely accepted open data formats that can be easily ingested into, and used by, a wide variety of both free and commercial geospatial software. We specifically make our data ***Reusable***. All input data used to create our outputs, as well as all computer code and models, are retained and provided so that anyone can reuse our data or models to reproduce our results or produce new results of their own. In most projects with a spatial analysis component, a very significant proportion of the total effort is expended in simply finding, downloading, assembling and preprocessing necessary spatial data sets.

[5] https://www.worldwildlife.org/threats/soil-erosion-and-degradation
[6] https://doi.org/10.1016/j.geoderma.2013.10.007
[7] https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/
[8] https://dx.doi.org/10.1038/d41586-019-00669-x
[9] https://www.nature.com/articles/sdata201618

If projects can obtain and reuse data that we have previously assembled and made available, much unnecessary duplication of effort can be avoided and the resulting savings in time and effort can be reallocated to doing the actual analysis that the spatial data are meant to support.

Our aspirations: Partnering with others active in critical application areas

OpenGeoHub wants to embed LandGIS spatial data and methods directly into critical analysis and decision making applications. ***The data by themselves are of no real value until they are used.*** So, we will reach out to governmental and development agencies, NGOs, companies and any interested entities to ensure that our data can be directly ingested into, and used to support, their application needs. We will offer to become partners in providing back office facilities and support in the areas of collecting, producing, hosting and distributing spatial data that users require to implement their own mandates. We do not have their mandates, nor do we aspire to claim them. But we do feel we have a mission to collect, produce and serve high quality geodata in groundbreaking ways that agencies that do have mandates in application areas would not be able to develop and support internally themselves.

We specifically aim to be disruptive and unconventional. We do not ask permission of any authority first before we produce data. Because we are independent and unaffiliated, we believe that we can reach out to, and work with, the widest possible audience of potential users without restrictions imposed by political, economic or cultural considerations. We believe that our efforts can help to de-commercialize and democratize the production, dissemination and use of critical environmental information worldwide.

Some examples: Critical application areas

We believe that urgent improvements to food production and food security will be hampered without ready access to up-to-date soil and land information. The OpenGeoHub Foundation was founded to contribute to a revolutionary shift toward supra-national open science, to build upon over a decade of effort to collect, process and publish environmental data — particularly focused on soil and to support diverse stakeholders in environmental stewardship and improved management. In addition to just data, we create tools for its exploitation, learning resources, host conferences/classes, and provide advisory services to governments and private organizations. Our open review process adds a further stage of rigorous peer review and analysis, prior to endorsement of data to a user community.

Beyond data generation, distribution, and exploration, OpenGeoHub has been in discussions to contribute to open-source (meta-)enterprise software being developed to drive business process innovation on the basis of environmental performance. The aim is to provide state-of-the-art infrastructure, platforms, and features for environmental value-creation. Functionalities in development include:

1. **Multi-user**: Relevant and useful functionality for various participants in environmental activity, including landowners, community leaders, scientific advisory agencies, sub-contractors, donors and investors.

2. **Multi-module**: various activities in environmental management are being integrated, including project discovery, farm due diligence, fundraising, implementation, automated KPI (Key-Performance-Indicator) tracking.

3. **Integrations with enterprise IT** (jointly developed with the Humboldt Environmental Systems Ltd[10]) and social media to add enhanced security, data protection, and interoperability features.

4. **Context-based customization** and enrichment:

    a. Spatially auto-filled user data (saving manual setup effort),

    b. Peer activity-based features,

    c. Location based alerts for specific conditions (e.g. frost warning, temperature thresholds etc)

5. Integration of **'blockchain' capability for environmental token trading support**.

With both the data and functionality roadmaps, an end-to-end proof of concept using OpenGeoHub data and methods is currently under construction.

How our work contributes to innovation in global soil information

We help transfer soil data from data rich to data poor countries making a win-win case for everyone

We believe that our work actively contributes to innovation in soil information most notably because:

- We have shown new added-value information can be produced immediately and affordably using "old legacy data" to generate high quality soil insights without new investments i.e. by importing, cleaning and data mining legacy soil data (Fig. 3). This allows **technology and knowledge transfer (from data-rich countries to data-poor countries).**
- We have released all code as open source, allowing **full replicability of state-of-the-art spatial analytics by anyone**, including as a basis for commercial services.
- We have released all data as **open data, allowing anyone, including businesses, to build upon this soils data — hopefully in ways we can't even imagine!**
- We have focussed on the world and not just on 'rich' countries — **the importance of comprehensive, continuous, correct and current soil information is without borders** (read more)**.**

The importance of rescuing legacy soil data (old soil surveys, reports, local soil studies even historic photographs of soil and land cover) is outlined in detail in the following documents:

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

Hengl T, Heuvelink GBM, Kempen B, Leenaars JGB, Walsh MG, Shepherd KD, et al. (2015) **Mapping Soil Properties of Africa at 250 m Resolution: Random Forests Significantly**

[10] https://www.humboldt.environmental.systems/

Improve Current Predictions. PLoS ONE 10(6): e0125814. https://doi.org/10.1371/journal.pone.0125814

Arrouays D., Leenaars GB, Richer-de-Forges AC, Adhikari K, Ballabio C, Greve M, Grundy M, Guerrero E, Hempel J, Hengl T et al. (2017). **Soil legacy data rescue via GlobalSoilMap and other international and national initiatives**. GeoResJ 14. Elsevier:1–19. https://doi.org/10.1016/j.grj.2017.06.001

We have also been active in **establishing automated systems for mapping soil nutrients in Africa**, and have been genuine promoters of Open Soil Data and reproducible procedures. Soil macro and micro-nutrients are critical limitations for plant growth in many regions. Additionally, we are active in **creating optimised sampling design algorithms for soil carbon inventories**:

Hengl, T., Leenaars, J. G., Shepherd, K. D., Walsh, M. G., Heuvelink, G. B., Mamo, T., et al. (2017) **Soil nutrient maps of Sub-Saharan Africa: assessment of soil nutrient content at 250 m spatial resolution using machine learning**. Nutrient Cycling in Agroecosystems, 109(1), 77–102. https://link.springer.com/article/10.1007/s10705-017-9870-x

de Gruijter, J. J., I. Wheeler, and B. P. Malone (2019) **Using model predictions of soil carbon in farm-scale auditing-A software tool**. Agricultural Systems 169: 24-30. https://doi.org/10.1016/j.agsy.2018.11.007

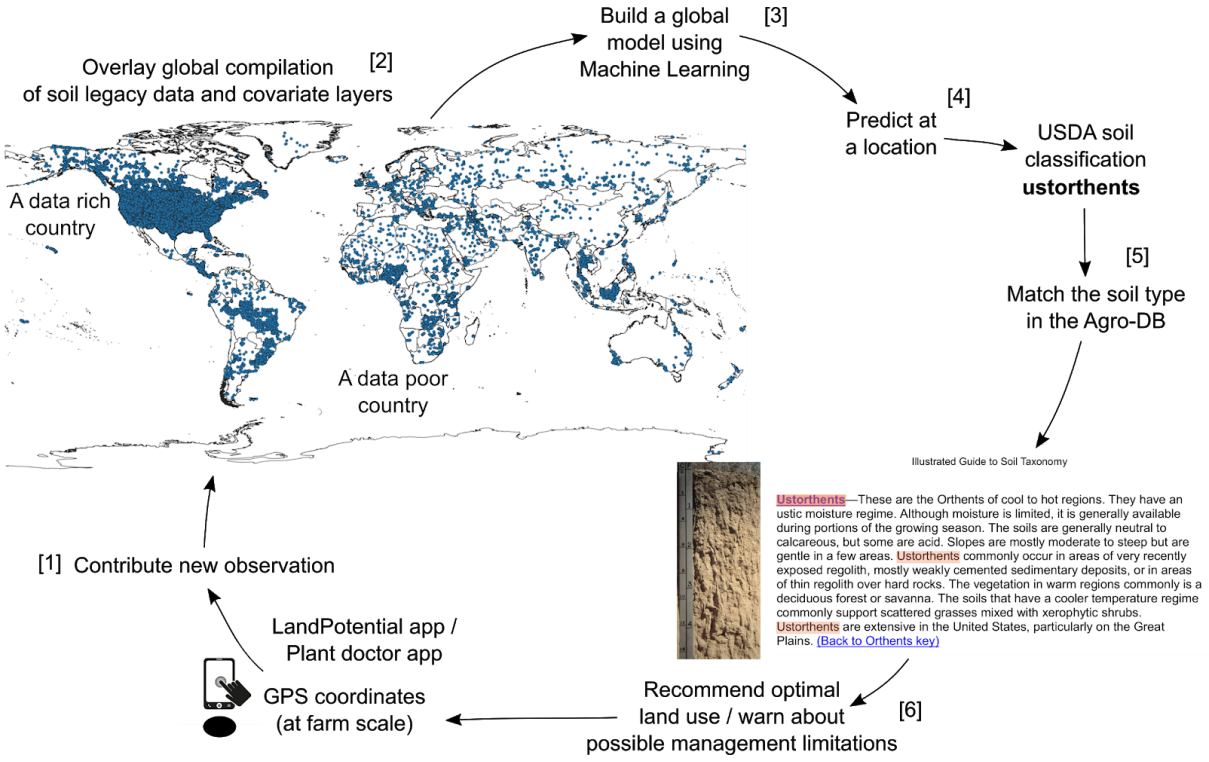

Fig. 3: Example of a general workflow of how LandGIS can be used to recommend optimal soil use practices at farm scale based on accurately predicting the soil type on the field (in this case the USDA great group). Note that USDA and other agricultural organizations have already spent billions of dollars to produce this type of knowledge, hence no additional investments are required from the USDA side.

We have proven capacity and enthusiasm to deliver better and better soil data across borders

It is estimated that worldwide there are millions of soil sample observations (when considering different languages, institutions and disciplines) which are currently stranded and uncollated. This doesn't even count new sources of soil data being collected today! **All this soils data is precious.**

Currently, OpenGeoHub has compiled the largest known global database of over 360,000 unique soil sample observations (made publicly available via producers websites or public repositories) to make predicted soil property maps from this data. We estimate that there are at least a few million of field sites with soil observations and measurements that have not yet been utilized for generating gridded soil information using state-of-the-art predictive soil mapping.

The (machine learning) methods used to generate our maps will allow **dynamic updates of new maps to be created** after users add new soil observations — both freshly collected or 'rescued' legacy data. The same feature also means local users can access the same type of dynamic mapping functionality but at finer resolution. For example, a farm being able to map it's nutrient status for the season for precision agriculture and similar. We are fully aware that future soil data users will need updates at weekly or daily basis.

We hope to continue collating open soils data at a global scale, including making a crowdsourced collation system for multi-scale soil property maps to be dynamically updated, keeping the soil products relevant and up-to-date. This way, **data doesn't get orphaned** and countries without the infrastructure to make such products can use the global system as a 'back-end' for their national systems, allowing access to full functionality for prediction, functionality, archiving and storage of soils data, whilst still **encouraging sovereignty and ownership of information**.

We cannot afford the duplication of effort to have 190+ unique soil information systems in the world that do not talk to each other — soil-environmental relationships extend across borders and we are better off sharing and enabling everyone to have the best soils information we can create together.

Other aspects we would seek to rapidly develop include:

- **Hyper-resolution data**:
    - The current LandGIS system could be gradually improved towards a spatial resolution of 100 m, 30 m or even finer. Methodologically there are no real obstacles to this, but finer resolutions would certainly require much more ambitious IT infrastructures.
- **Sampling and monitoring functionality** for:
    - Soil organic carbon inventories over large areas (catchments, regions, countries) and including optimised designs[11], automated calculation of soil carbon maps and carbon inventory statistics and verification functionality — anywhere on the globe.
    - Soil nutrient mapping for land capability/diagnostic assessment (e.g. sampling design to provide maps of soil variables where certain critical thresholds exist for plant growth, such as pH <5.5, micro-nutrient deficiencies etc.).

[11] https://doi.org/10.1016/j.agsy.2018.11.007

- **Multi-language interface**: much of the world does not speak English and many of the researchers in our network could help greatly with translation of interfaces, key materials and tutorials
- **Per-pixel uncertainty for all maps**: to enable new improved sampling designs.
    - Allowing thresholds to be accurately identified (e.g. allowing precision agriculture to be based on statistically different patterns in soil, not just generic breaks), and to date, has not been applied as a method for per pixel uncertainty from ensemble machine learning has only just being developed by our team in the last months.

How does OpenGeoHub act as an ambassador for improving soil information?

We know soils and enjoy getting our hands dirty. We have helped articulate visions and led technical discussions and activities aimed at achieving the vision of highest quality soil information. For over a decade we have been directly involved in designing, testing, implementing and promoting global soil data systems (see e.g. Fig. 4). **We bring open data, open ideas and open hearts.** We genuinely believe in a better tomorrow, and that this comes from working together and empowering people to tackle our common challenges, with a big 'family' supporting them.

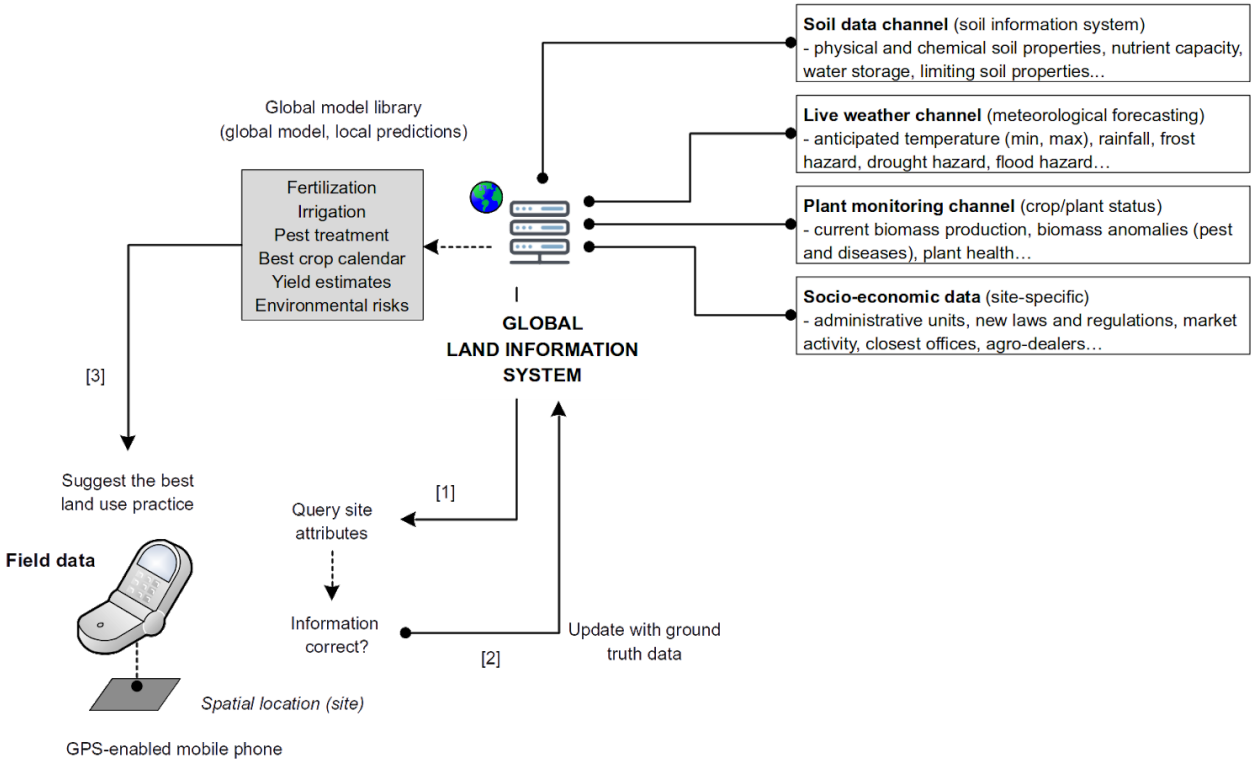

Fig. 4: We envision an Open Global Land Information System (inspired by the Global Soil Information Facilities project) based on cloud computing and global compilations of soil, weather, plant and socio-economic data, in which local observations would be used to re-calibrate global models.

Our Foundation personnel are active in engaging audiences to promote soil information and assist in improving its creation and use. We have experience working in many different countries and with a diverse array of stakeholders — from UN country Party delegations, to European Space Agency[12] and up to farmer groups in the field. We are located in Europe and in Canada, making most destinations reachable. Additionally, the wider OpenGeoHub network of affiliated and supportive researchers is spread across the world representing all major language groups.

Ongoing OpenGeoHub development efforts focus on improving engagement with data and monitoring activities by private-sector actors. Partners of the organization in this include environmental restoration 'project developers,' hardware and software technology providers, educational institutions, and consultants. We are specifically working closely with our partners the IIASA institute (http://www.iiasa.ac.at/), the International Soil Modeling Consortium (https://soil-modeling.org/), and the LandPotential project (https://landpotential.org/). We hope to engage OpenGeoHub, as well as its backers, to further the ideas under innovating soil information.

We are now expanding our efforts from mainly just serving up-to-date, free and open, soil and environmental information, to increasingly focus on **revolutionising the generation of new open soils data itself** for the purpose of land restoration, recovery of ecosystem services, and associated measurement monitoring and verification services.

OpenGeoHub is ambitious and enthusiastic about contributing to a revolution in how data about soil, land and the environment in general is produced, disseminated and used globally:

1. **On the production side, we want to accelerate and improve the production of soil and environmental data globally** by:
    - Providing concrete, real world, worked examples that demonstrate conclusively that relevant, useful and accurate soil information products can be produced rapidly and affordably, right now, using currently available data, computing tools, resources, infrastructure and personnel.
    - Providing a platform and mechanisms which encourage others to contribute to the creation of new global (to local) soil information products and that facilitate and support these contributions by a wide community of potential contributors.
    - Creating a working system that encourages and supports changes in thinking that will result in acceptance of, and enthusiasm for, the collection of new field soil observations and measurements that, in turn, will support the production of higher quality, next generation soil and environmental information products at global to local scales.
    - Contributing to the development, application, evaluation and acceptance of new methods and best practices for producing soil spatial information products, in particular global models, 3D space-time models and multi-scale models.
2. On the data dissemination side, **we want to disrupt current models that restrict and limit distribution and use of soil and land information** by:

[12] http://worldsoils2019.esa.int/page_Committees.php

- Providing a platform where all manner of relevant environmental data can be hosted and made free and easy to discover, easy to assess, easy to review and easy to download.
- Opening up our platform for others to use to make their own data widely discoverable and useable by the broadest possible community of users.
- Pushing current limits to enable effective presentation, review and download of more complex 3D space-time spatial data sets.
- Helping to change the perception of maps from one of static representations of non-changing conditions to one of dynamic representations of conditions that can, and do, change in time, space and with depth.

3. On the data use side, we want to **ensure that data get widely and profitably used** to
    - Reach the widest possible user audience without restrictions imposed by political, economic or technology exclusion.
    - Be easily ingested into existing and new decision making and modeling algorithms without any need for laborious conversions, transformations or interpretations.
    - Support efforts to change land management practices towards those that restore and regenerate soils and the environment.
    - Monitor and model changes in soil and other environmental qualities through time so that we have effectively established global frameworks and platforms for recording and monitoring changes in soil and environmental qualities through time.
    - Democratize and de-commercialize the production, dissemination and use of critical environmental information worldwide.

Appendix

The OpenGeoHub management board biographies

Dr. Bob. MacMillan

Robert A. (Bob) MacMillan began his career as a soil surveyor at the Alberta Research Council (Canada) in 1976, and led the Soil Inventory Section from 1984-1987 when he took leave to pursue a Ph.D. At ARC Bob was responsible for introducing the use of GIS, geostatistics, DBMS, and automated analysis of DEMs for soil surveys in Alberta. Working in Tanzania from 1982–84 on secondment to CIDA, Bob produced soil surveys, developed and implemented farm scale conservation plans for extensive wheat farms and carried out grid soil surveys for research farm plots.

Bob conceived of, wrote and applied a set of programs (LandMapR) for applying fuzzy logic to elevation and other data to automatically classify and map landforms, ecosites, soil units and hydrological spatial entities (streams and ponds). Bob personally applied these programs to millions of ha of landscapes in Canada, and assisted others to apply them to millions more in Canada, the UK, Brazil, USA, Germany, Australia, Indonesia and Ireland. Many individuals practising automated mapping in Canada were first introduced to the discipline through Bob, via the LandMapR programs.

As Science Coordinator for the GlobalSoilMap project, Bob helped to articulate the vision for the project and led initial activities aimed at achieving this, including authoring technical specifications, promoting the project, recruiting participants and cooperators and liaising with representatives of national and international soil agencies. Bob's current passion is to support the next generation of innovators in soil information, specifically those contributing to OpenGeoHub and AfSIS Ltd.

Appointments:

- 2018–present: Chair OpenGeoHub Foundation, Board member AfSIS Ltd.
- 1994–present: Principal LandMapper Environmental Solutions Inc., Canada.
- 2009–2012: Science Coordinator for GlobalSoilMap, ISRIC, Netherlands.
- 1976–1994: Senior Research Officer for Alberta Research Council.

Education:

- PhD '94 in Geography (GIS and Environmental Modelling), U. Edinburgh.
- Master of Science (MSc) '82 in Soil Sciences, U. Alberta.
- Bachelor's (BSc) '75 in Geology/Earth Science, Carleton U.

Previous projects and initiatives:

- Promoter, advisor and editor for papers/reports for ISRIC
- Member of the Project Advisory Committee (PAC) for the Africa Soil Information Service (AfSIS).
- Member of the Board for AfSIS Ltd.

Dr. Tomislav Hengl

Tomislav (Tom) Hengl has 20 years of experience as an environmental scientist and data analyst, having published >50 journal articles and several textbooks in fields of geo-information science and soil mapping. Tom created a package in R called "plotKML" to produce visualizations of complex spatial/spatiotemporal phenomena, and is a recognized expert in Geomorphometry, Spatial Statistics and Pedometrics, Machine Learning and Big Geodata for environmental modeling. Tom obtained his PhD in 2003 from Wageningen University in Pedometrics.

Tom's efforts increasingly focus on processing of very large data sets across global to local scales, using space-time modeling. He has contributed to projects of organizations including The Nature Conservancy, Woods Hole Research Inst., Bill and Melinda Gates Foundation, UNCCD, Africa Soil Information Service (AfSIS), and Dutch Environmental Agency (PBL).

As an advocate of open data, reproducible science, collaboration between fields, and the need for strong technological capabilities if global environmental problems are to be addressed, Tom designed and implemented SoilGrids inspired by projects such as OpenStreetMap, Global Biodiversity Information Facility, Global Forest Watch and open climate mapping projects. In addition to OpenGeoHub, Tom prepared a textbook on use of Machine Learning to address applied environmental problems as a potential replacement for more traditional model-based geostatistics. Also, since 2007 he delivers courses training postgraduate students and early career scientists in Open Source Software tools (R / OSGeo) for spatial statistics and spatial analysis.

Appointments:

- 2018–present: Vice-Chair OpenGeoHub Foundation
- 2018–present: EnvirometriX Ltd., Netherlands.
- 2010–2018: Senior researcher, Wageningen University / ISRIC, Netherlands.
- 2007–2010: Post-doctoral researcher, U of Amsterdam, Netherlands.
- 2005–2007: Post-doctoral researcher, European Commission JRC, Italy.
- 1998–2005: PhD student / Ass Professor, Croatia / Netherlands.

Education:

- IBED / University of Amsterdam (Ecology / biodiversity) Post-doc, 2010
- JRC European Commission (Soil science / Pedometrics) Post-doc, 2007
- ITC / Wageningen University (Geoinformation science) Ph.D., 2003
- ITC Enschede (Soil Resource Management) M.S., 2000
- University of Zagreb (Forestry) B.S., 1996

Previous projects and initiatives:

- Mapping soil carbon (agriculture, mangrove) for The Nature Conservancy.
- Project leader Global Soil Information Facilities 2011–2016.
- Creator & convener, GEOSTAT Summer school for PhD (Site).
- Vice Chair Int. Society for Geomorphometry (Site) 2011–2015.
- Editor Hydrology and Earth System Science (Geomorphometry issue 2009, 2016).
- Editor Earth Surface Dynamics special issue on Geomorphometry (2014).
- Editor Hydrology and Earth System Science Geomorphometry issue 2009.
- Editor / lead author Geomorphometry book (www.geomorphometry.org/book).

Dr. Ichsani Wheeler

Ichsani (Ish) Wheeler developed a deep bond with nature as a home-schooled permaculture kid in the remote Australian outback. Ish graduated from Sydney University with a Bachelor of Land and Water Science and, after a foray into the design and development industry, returned to a postgraduate program in soil and agricultural science. In 2014 Ish completed a PhD on "The auditability of soil carbon at the farm scale" at U of Sydney, which involved devising and demonstrating patentable methods to quantify soil carbon at the farm scale, as a prerequisite to enabling soil carbon offsets and trading.

Ish moved to the Netherlands as a consultant in the area of sampling, mapping and quantifying spatial distribution of soil carbon at global to field scales. Her most recent work has been with the UNCCD, focused on Soil Organic Carbon (SOC) for Land Degradation Neutrality and degradation hotspot analysis for >100 countries. Current responsibilities include supporting providing the SOC global default data and calculation of SOC change 2000-2015 globally, supporting and training country teams to report on LDN and SDG indicator 15.3.1. 'Proportion of land that is degraded over total land area.'

Ish well versed in managing complex projects as well as coordinating large groups of people (30+) in training and collaborative work environments, primarily acquired through: teaching, consultancy, postgraduate studies and freelance contracting, technical classes, tutorials and community workshops. Additionally, she is experienced in working with a wide range of cultures in a variety of settings, delivering both highly technical training materials as well as beginners guides, and is able to adapt her style to suit the goals of the group.

Appointments:

- 2018–present: Management Board OpenGeoHub Foundation
- 2018–present: Senior Lecturer, Farming Systems Ecology, WUR
- 2017–2019: Social Media Manager, Soils For Life advocacy
- 2014–present: EnvirometriX Ltd., Netherlands.
- 2014–2018: Consultant, Data analytics, UNCCD
- 2007–2009: AECOM, Water Sensitive Urban Design

Education:

- PhD in Soil carbon auditability at the farm scale, University of Sydney, 2009–2014
- Bachelor of Land and Water Science (Class I Honours), U of Sydney, 2004–2007

Previous projects and initiatives:

- Global analysis for indicators under Sustainable Development Goal 15.3.1 - proportion of degraded lands (UNCCD).
- Country level capacity building & training for reporting to UNCCD process.
- Global degradation indicator and hotspot analysis for Land Degradation Neutrality Target Setting Programme (UNCCD).
- Soil carbon baselining for mixed, grain and grazing farms in SE Australia - assessment of commercial viability in the framework of legislated Australian carbon farming methodologies.