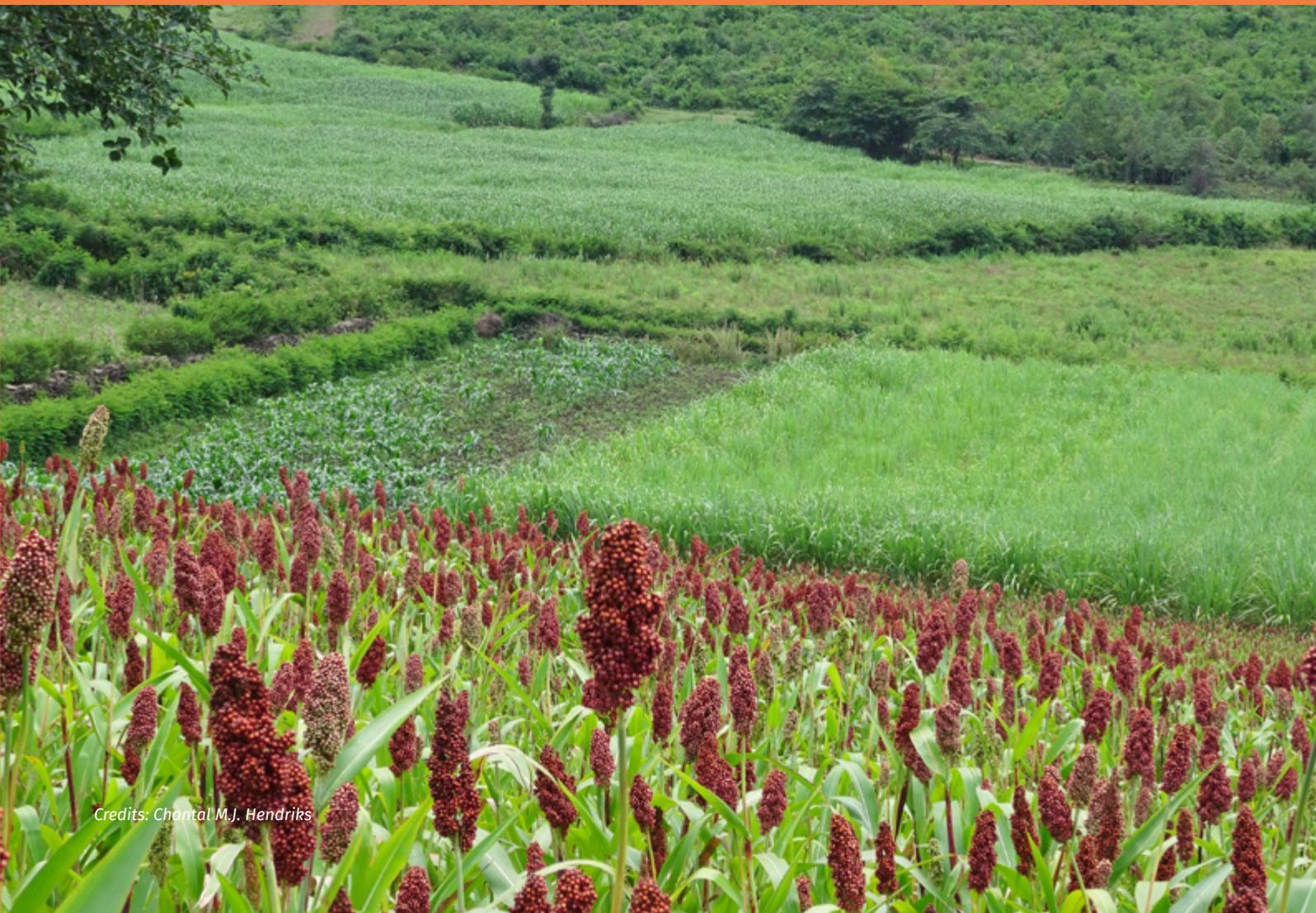




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# Institutional and international developments

## 50th Anniversary

2016 was a special year for us. It marked 50 years since the establishment of ISRIC, which has seen its evolution from the International Soil Museum to a soil reference and information centre accredited as World Data Centre for Soils (WDC-Soils) by the International Council for Science (ICSU) World Data System (WDS).

The anniversary celebrations began with some smaller events and culminated with a special day held for staff, former colleagues and friends. Dr David Dent (a former Director), Professor Emeritus Dr Johan Bouma (Honorary Fellow and former long-time member of the ISRIC Board), and ISRIC Director Rik van den Bosch gave presentations that addressed past, present and future aspects of the institute, and an acknowledgement of the growing scope and breadth of ISRIC's activities. In the midst of the celebrations, Professor Seppe Deckers and Dr Bob MacMillan were appointed as Honorary Fellows in recognition of their long-term and outstanding support of ISRIC.

## Strategy development and implementation

We refined our medium-term strategy, which included redefining our mission statement and structuring our four work streams.

In the first work stream (*Standards and reference*), we strive to be part of international standard-setting processes for soil mapping and soil classification, soil measurements and standards for data exchange and interoperability of soil data. The GODAN (Global Open Data for Agriculture and Nutrition) Soil Working Group was founded by ISRIC and Pillar 5 of the Global Soil Partnership as a platform for further development of standards for open soil data. In 2017, we finalised a 7-year activity to expand the World Soil Reference Collection by an additional 75 monoliths in an effort to obtain full coverage of the major soil groups of the world. We now provide full access to many parts of our collections through web services. In the second work stream (*Soil information brokering*), we follow a hybrid approach. We assist partners in their efforts to build national and regional soil data information systems through



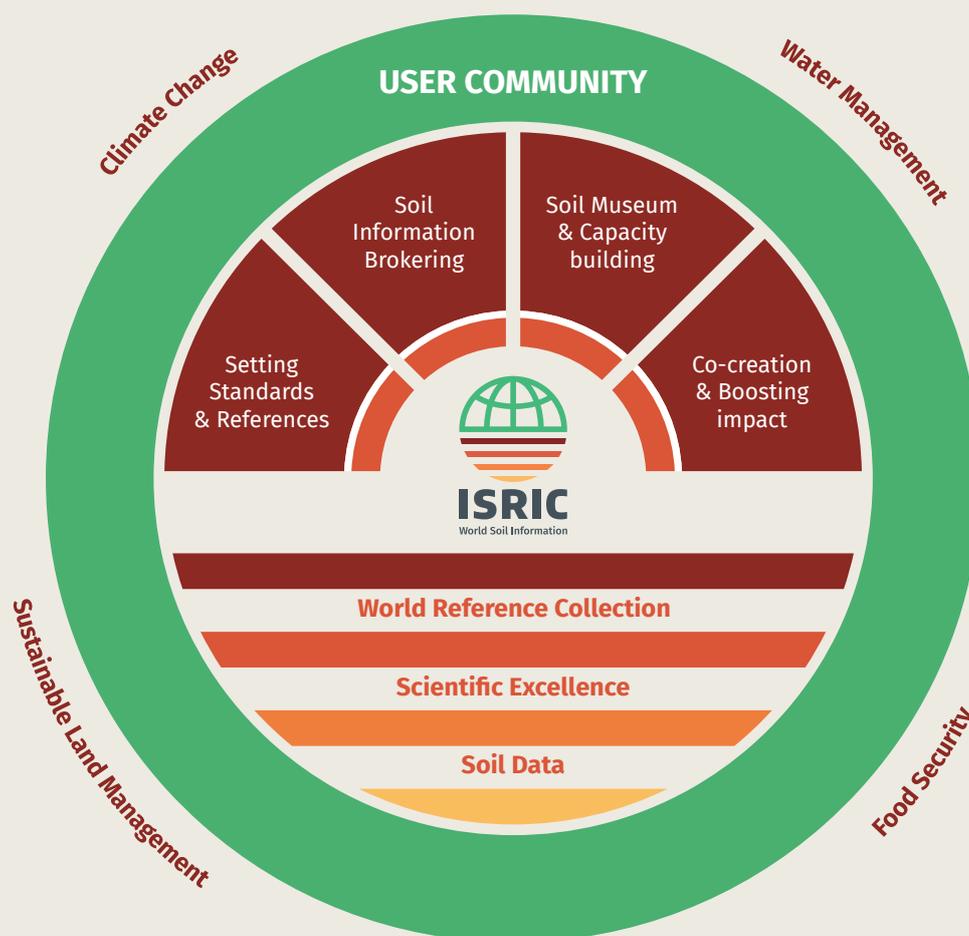
Meet our new Honorary Fellow, Dr Bob MacMillan (Canada)

capacity building and information supply. At the same time, we build global soil information products, by collating available soil information and environmental covariates, used primarily for global studies and assessments. The two-pronged approach enables us to serve different users and create synergies that lead to enhancement in the quality and range of information products generated.

For example, we were able to increase the number of profiles in the ISRIC institutional soil database (WoSIS, World Soil Information Service). Once the data were standardised, they were made freely available to the international community. Further, we released a new version of our global gridded product (SoilGrids) with a resolution of 250m and increased accuracy compared with the previous versions. Nevertheless, we need to develop the product further to improve accuracy and provide confidence limits for the predictions. We are working on a procedure to improve prediction of soil classes. Based on this experience, we released a soil nutrient map for Africa and various products providing insight in national level soil organic carbon (SOC) stocks. These data have been used by the UNCCD (United Nations Convention to Combat Desertification) to provide member countries with information

on baseline soil organic carbon stocks in support of their Land Degradation Neutrality reporting. In the third work stream (*Building an effective user community*), we work on dedicated capacity building programmes as well as engage with potential users from the soil science and other communities to boost the use of our products and receive feedback for further improvement. The World Soil Museum is an important venue for informing people about soils and their functions. And it is here that part of our annual Spring School on 'world soil assessment' and 'digital soil mapping' is held. We also organise various tailor-made courses on digital soil mapping abroad.

In the fourth work stream (*Derived products*), we actively engage with potential users of soil information to develop derived information products geared towards their specific needs. In 2017, we started a project for a fertiliser company to provide spatial information on nutrient limitations for selected crops, as a basis for the development of site-specific nutrient formulations. We also cooperated in various projects on sustainable land management by providing soil data and our expertise. One of these projects is leading to the development of an interactive mobile phone app, which will provide insight into soil quality in Europe and China.



ISRIC's four work streams, supporting services and main thematic focus areas

### **Soil Data Facility for the Global Soil Partnership**

In July 2017, ISRIC was nominated to host the Soil Data Facility (SDF) for the Global Soil Partnership (GSP). This means that ISRIC will contribute to the design of the Global Soil Information System, participate in capacity building programmes, and host a system that integrates the national and regional facilities into a federated, global soil information system. We are proud to be entrusted with this important role by the Plenary Assembly of the GSP. As SDF, we will work closely together with the Pillar 4 Working Group and the International Network of Soil Information Institutions (INSII) to create a distributed soil information system to contribute to the sustainable use of global soil resources.

### **LDN Target Setting Programme**

We supported the Land Degradation Neutrality Target Setting Programme (LDN TSP) implemented by the UNCCD Secretariat and the Global Mechanism. This programme aims at assisting countries to report on LDN by (amongst others) compiling and making available global datasets required for monitoring changes in LDN indicators. ISRIC provided global and national data sets on soil organic carbon concentrations, stocks and trends to all countries participating in the programme through use of the SoilGrids framework.

### **Outlook**

We will continue to expand our soil information products and services with partners and users. To this end, we will further improve and automate the procedure for data intake, control and standardisation/harmonisation, as well as the procedures for producing gridded products. We have a special focus on the development of procedures for mapping soil organic carbon (SOC) sequestration potential. An accepted standard for soil data interoperability is indispensable here and we are dedicated to contribute to this.

Much of this work is preferably done through the mechanisms of the Global Soil Partnership. ISRIC will further expand its on-line user community for help with product development and to receive user feedback for continuous improvement of the products. We will expand our efforts to apply the available soil information, especially in the field of soil fertility and sustainable land management.



*Towards sustainable soil and water management, Machakos County, Kenya (Credits: Chantal M.J. Hendricks)*



Collecting a soil monolith in Indonesia

## Standards and reference

ISRIC has a mission to serve the international community as custodian of global soil data and information, and to increase awareness and understanding of the role of soils in major global issues. This requires adherence to internationally endorsed standards for soil sampling, soil measurements (using conventional methods and soil sensing), soil classification and soil mapping, as well as working towards new standards in collaboration with partner institutes.

### *Enhancing the World Soil Reference Collection*

Over the past seven years, our collection of reference soil monoliths was enhanced within the framework of the 'Soil Exploration and Sampling for Science and Education' (SOLEX) project. In 2016 and 2017, we collected a total of 66 new

monoliths in Indonesia, Ghana, Jordan, Morocco and Russia. All of the monoliths, except for those collected in Morocco, have arrived at ISRIC for further processing. To date, 61 monoliths have been prepared in the ISRIC workshop using newly tested, water-based, impregnation techniques. Field samples for the newly collected soil monoliths were shipped to the USA for chemical analysis at the Kellogg Soil Survey Laboratory (KSSL, Lincoln). Soil physical measurements (pF rings for moisture retention) were performed in the soil physics laboratory of Wageningen University & Research. In combination with the above, the storage, registry system, documentation and accessibility of the entire collection (samples, hand specimens, and monoliths) was improved considerably. In November 2017, the new additions were digitised and incorporated into our centralised soil database (WoSIS). The soil reference collection can now be consulted through various web-based platforms, including our virtual soil museum.



*Referencing soil sample jars using bar codes for registration in WoSIS.*

We are grateful to our partners, in the aforementioned countries, for the assistance they provided in selecting, sampling and shipping the monoliths and to KSSL for freely analysing the reference samples. The SOLEX project, which ends in 2018, is co-funded by the Netherlands Ministry of Agriculture, Nature and Food Quality, Wageningen University & Research, and ISRIC.

#### *Towards standards for data inter-operability*

Developing standards is a continuous effort. We do this with many partners, for instance within several IUSS Working Groups (WG-SIS on 'Soil Information Standards' and WG-WRB on 'World Reference Base for Soil Resources'), Pillar 5 of the Global Soil Partnership on 'Soil Data Harmonisation', and the 'Soil Data' Working Group of GODAN. An important effort now is to arrive at a mutually endorsed, operational procedure for the worldwide inter-operability of standardised soil data.

#### *Soil sensing*

Remote and proximally-sensed data are increasingly used and accepted for a range of applications in the soil domain. In recognition thereof, since 2016 we have been assessing how such techniques may be used in our work, in particular how such data may be incorporated in our centralised soil database (WoSIS) to complement our current selection of legacy-data. This will require sharing of soil spectral libraries, which provide the link between sensing data and lab-determined soil properties. For this, we depend on our partners and participate in the IUSS Working Group on Proximal Sensing. Further, we cooperate on soil sensing with Wageningen Environmental Research and the Soil Geography and Landscape chair group of Wageningen University.

# Soil information brokering

## *World Soil Information Service*

With our partners, we have further developed WoSIS (World Soil Information Service), a centralised server database based on PostgreSQL. New soil profile data, shared by a growing number of soil data providers worldwide, are first stored 'as-is' in the ISRIC WDC-Soils data repository with their metadata. Subsequently, all point data shared with us under a 'non-restrictive' licence are imported into the WoSIS data base for further standardisation and harmonisation.

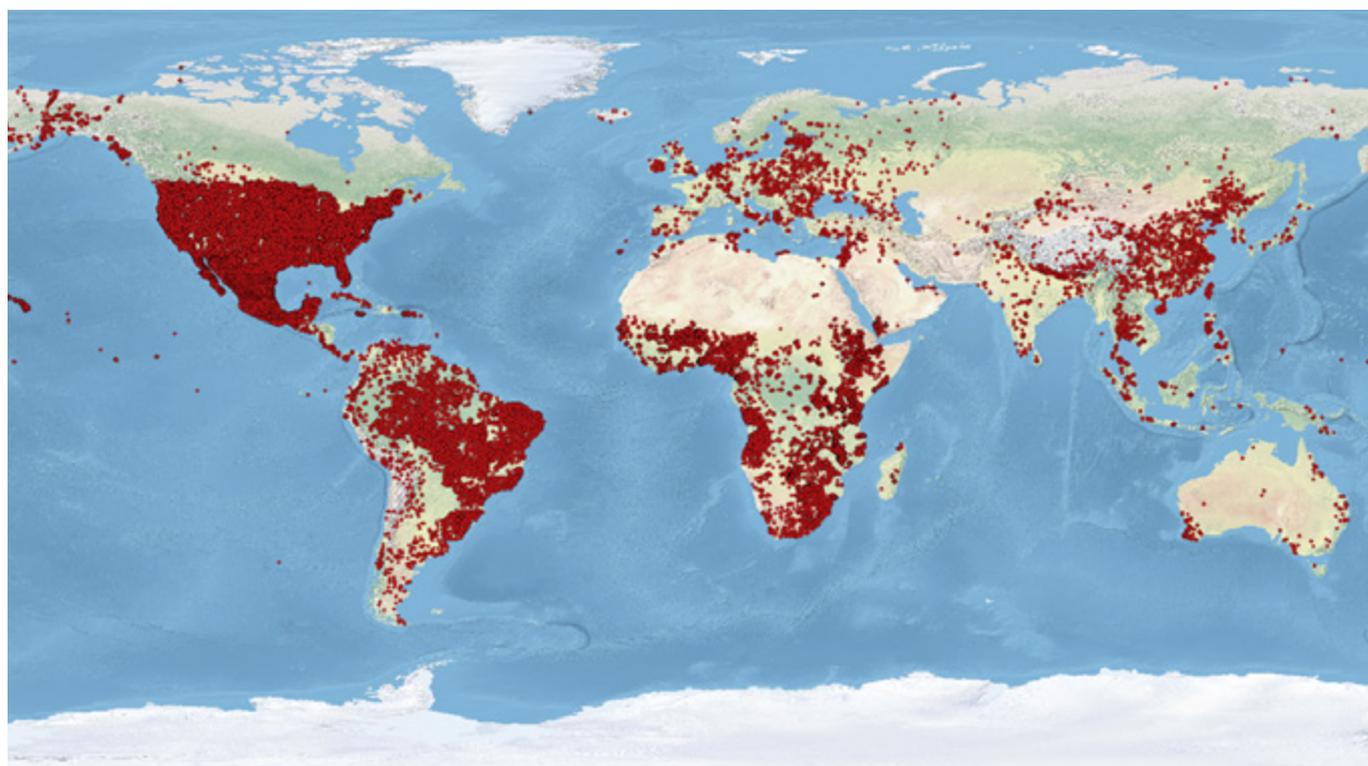
In view of the magnitude of the task, we started with the selection of soil analytical and physical properties considered in the *GlobalSoilMap* specifications. The most recent set of standardised data is provided freely to the international community via a web feature service (WFS). The size and content of this *dynamic* data set will change as new datasets are submitted and processed, or holdings are amended. For consistent citation purposes, we provide static datasets or snapshots of the standardised data with a DOI (Digital Object Identifier). New snapshots will be generated once data for some 50,000 new profiles have been standardised in WoSIS.

## *Soil property maps for Africa*

In 2016, we released updated soil property maps for Africa at 250 m resolution for six standard depths up to 2 m depth. Cross-validation showed that these maps are considerably more accurate than the initial 1 km product that was released under Phase 1 of the Africa Soil Information System (AfSIS) project. Reasons for the improvement are the use of high-resolution covariates, legacy as well as sentinel site data, and machine learning algorithms. As a follow up activity, we generated maps of soil nutrient content (0-30 cm) across sub-Saharan Africa, at a spatial resolution of 250 m. These maps are increasingly being used for a diversity of applications by organisations such as IFPRI (International Food Policy Research Institute), HarvestChoice, OFRA (Optimising Fertilizer Recommendations in Africa) and PBL (Netherlands Environmental Assessment Agency).

## *Soil property and class maps for the world*

Building on the above mapping approach for Africa, with our partners, we have implemented and developed a new generation of SoilGrids products at 250m resolution for the world. It consists of global predictions for standard soil properties (including organic carbon, bulk density, cation exchange capacity, pH, soil texture fractions and coarse



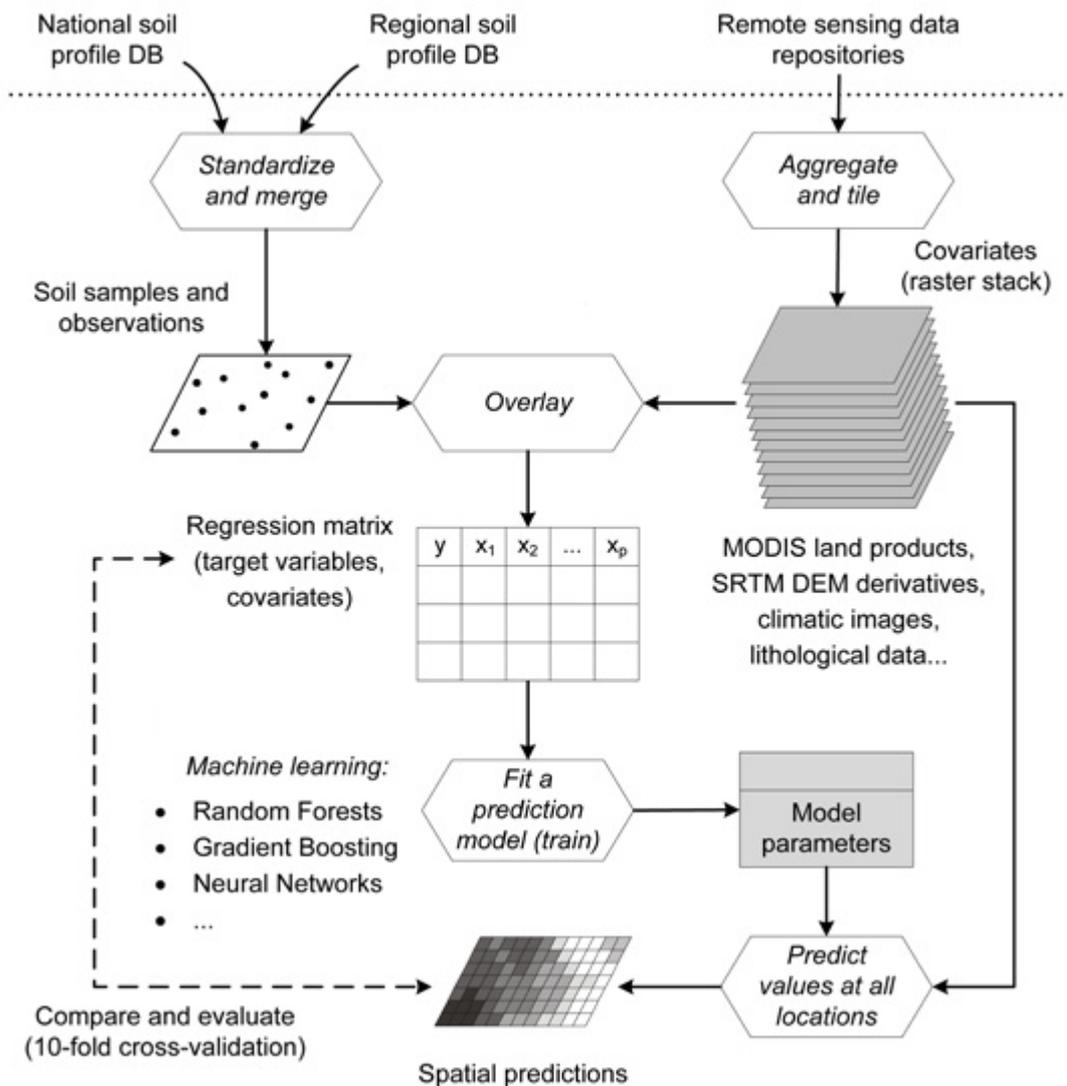
Location of standardised soil data served through WoSIS (December 2017)

fragments) at seven standard depths up to 2 m depth, the so-called *GlobalSoilMap* specifications. Further, predictions of depth to bedrock and distribution of soil classes based on the World Reference Base and USDA (U.S. Department of Agriculture) soil classification systems were generated. The spatial predictions are derived from a compilation of standardised soil profiles (WoSIS and auxiliary sources), a compilation of environmental co-variates, and R packages supporting soil data analysis using machine learning. The derived data are freely accessible under an Open Database licence through our Soil Data Hub and other web services. Besides ISRIC's own in-house improvements to the data and methodology, SoilGrids products are continually being improved based on user feedback via a mailing list and GitHub facilities. In conjunction with this, ISRIC organised a workshop on machine learning during the Pedometrics 2017 Conference

as well as a special session for users and producers of soil information during the 2017 Wageningen Soil Conference.

### Towards crowd-sourcing

SoilGrids layers can be queried in the field on a mobile phone, using SoilInfo app. The app is freely available from Google Play and the App Store. The functionality to upload soil data to a shared soil database, in conformance with FAO Guidelines for Soil Description, is being tested. In the future, this functionality may provide the basis for crowd-sourcing of soil data. In a similar vein, a group of researchers working on 'Open Soil Science Data and Technology' met at ISRIC in July 2017 to discuss current and future developments in citizen soil science.



Schematic representation of data-driven statistical framework for generating SoilGrids (doi: 10.1371/journal.pone.0169748)

# Building an effective user community

## *Developing the Soil Data Facility for the Global Soil Partnership*

Subsequent to an open-call to the soil science community and peer-review, ISRIC was selected to host the 'Soil Data Facility' (SDF) at the Fifth Meeting of the Global Soil Partnership Plenary Assembly (June 2017). The SDF forms the technical backbone of the GSP Pillar 4 on 'Information and Data', and is responsible for the design and development of the spatial data infrastructure of the Global Soil Information System (GloSIS). In 2018, we will start building the components for the system, with special attention paid to the technical specifications for the soil profile databases and proposed spatial data infrastructure for the SDF.

## *Capacity building on data handling and digital soil mapping*

In 2016, the GSP launched the 'Global Soil Organic Carbon' (GSOC) map initiative. The aim of this large international effort was to develop a 1 km resolution world map of soil organic carbon stocks (0–30 cm), drawing on country contributions. ISRIC was approached by the GSP to support the development of the GSOC map. We first contributed to a GSP User Manual,

which outlines in detail various methods for mapping SOC stocks, to underpin the worldwide GSOC training programme. Subsequently, with colleagues from Wageningen University, we provided an extensive training on data handling and digital soil mapping at our centre with 17 participants from 15 countries participating. The national maps at 1 km resolution, resulting from the training, were later merged into the overall GSOC product by the GSP Secretariat. As planned, the GSOC map was officially launched by the GSP on World Soil Day 2017 in Rome.

## *Training on digital soil mapping in South Asia*

CIMMYT, the International Maize and Wheat Improvement Center, contracted ISRIC to provide a hands-on training on digital soil mapping in Kathmandu, Nepal (27 to 31 March 2017). As a follow up, we were invited to give a similar training in Vijayawada, India (27 November to 1 December 2017). About 15 experts from various institutions in the region attended the training. This capacity building was of great strategic interest to us as it provided access to a region where ISRIC still has few projects. Further, the work provided a good opportunity to engage and collaborate with CIMMYT, a member of the CGIAR consortium.



*Participants and trainers of the GSOC training in Wageningen*

# Co-production of derived products

## Food security

### *Macronutrient and micronutrient mapping for sub-Saharan Africa*

With funding from PBL (Netherlands Environmental Assessment Agency) and in partnership with the AFSIS project, funded by the Bill and Melinda Gates Foundation (BMGF) and the Alliance for a Green Revolution in Africa (AGRA), we have estimated the content of soil macronutrients and micronutrients for sub-Saharan Africa. For this, we first generated 250m resolution soil nutrient maps using the SoilGrids predictive framework. These maps were then used for an exploratory assessment of nutrient stocks in this resource-scarce region facing rapid population growth.

### *Fertiliser recommendations for major crops in West Africa*

Site-specific fertiliser recommendations for major food crops in West Africa were prepared by ISRIC in collaboration with the International Fertilizer Development Center (IFDC) and experts from the NARs (National Agricultural Research Centre's) of Benin, Burkina Faso and Ghana. The project was implemented within the framework of the West Africa Fertilizer Programme (USAID WAFP), which IFDC is implementing in collaboration with the Economic Community of West African States (ECOWAS). The study provided a proof-of-concept for progressive updating and upscaling of fertiliser recommendations across the region. It made use of recently released, 250 m resolution soil nutrient maps and maps of attainable yield. Fertiliser recommendations were formulated on the basis of crop response data measured at selected trial locations. These data were first analysed using a crop yield model (QUEFTS, Quantitative Evaluation of Fertility of Tropical Soils). They were then extrapolated to propose maps of site-specific fertiliser recommendations for millet, sorghum, maize, rice and cassava across West Africa. The results were presented at the regional forum 'From soil analysis to delivering more profitable fertilizers to farmers' in Lomé, Togo (11-13 April 2017). The proof-of-concept was well received, providing an operational framework for future collaboration.

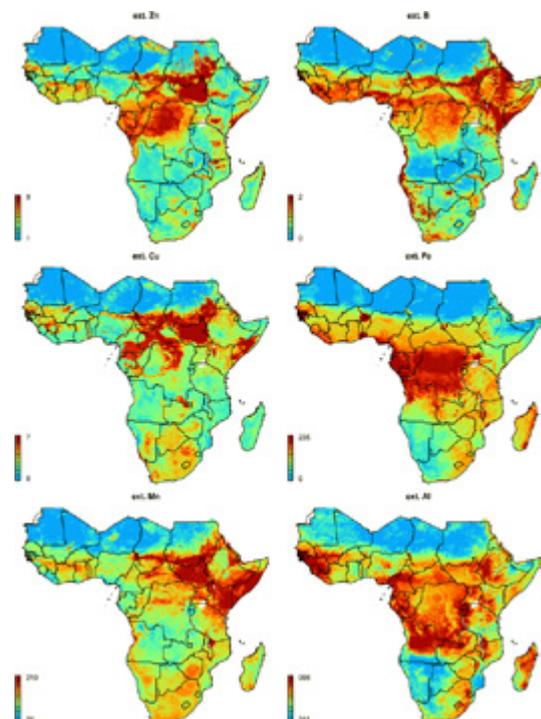
### *Micronutrients for better crop yields*

The project 'Micronutrients for Better Yields' (2016-2021) is being implemented by a consortium funded by Technology Foundation STW (part of Netherlands Organisation for Scientific Research, NWO), with Wageningen University, the

Virtual Fertilizer Research Centre (VFRC), SoilCares and ISRIC as partners. The aim of the project is to provide a scientific basis for accurate prediction of soil micronutrient availability and crop yield, at field, regional and national scales. So far, the project explored the feasibility of using available soil maps to assess soil fertility in Rwanda through a spatial application of the QUEFTS model. This model was further developed to consider Zinc as a possible limiting factor, in addition to NPK.

### *Development of a soil fertility and crop nutrient management platform*

A consortium involving ISRIC, Wageningen University & Research and the Nutrient Management Institute along with AfricaRice has been working towards site and crop specific fertiliser formulations for important crops and agro-ecosystems in sub-Saharan Africa. The project (2017-2021) was implemented at the request of the OCP (Office Chérifien des Phosphates). Initial results will become available in 2018, once results of the field soil-sampling programme have been processed. Ultimately, the consortium aims to deliver a broadly applicable soil fertility and crop nutrient management platform, which can be used to produce maps of fertiliser recommendations for sub-Saharan Africa based on nutrient gap analyses for defined crops in specific areas.



*Predicted soil micronutrient concentrations (0–30 cm) and extractable-Al for sub-Saharan Africa (All values are expressed in ppm, doi: 10.1007/s10705-017-9870-x)*



*Upland rice cultivation on slash-and-burn land in Kalimantan*



### *Enhancing rice markets in Uganda through smart micronutrient fertilisation*

The ENRICH project (2016-2018), 'Enhancing Rice Markets in Uganda through Smart Micronutrient Fertilisation', is aimed at increasing food security and income of smallholder farmers producing lowland rice in Eastern and Northern Uganda. ISRIC has been playing a key role in this project, providing maps of key soil fertility parameters (such as pH, soil organic carbon, macro- and micronutrients) using digital soil mapping. The project is funded by Technology Foundation STW and carried out by a consortium including the Africa Innovation Institute, AfricaRice, Wageningen University, the International Fertiliser Development Centre (IFDC), two private companies (Fica Seeds Ltd and WindWood Millers Ltd) and ISRIC.

### *Scaling up of evidence-based best practices in agricultural production in Ethiopia*

In the framework of the 'Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia' (CASCAPE) project (2013-2016), coordinated by Alterra, ISRIC carried out a soil characterisation and mapping study. Coherent information on soil-landscape resources for 30 *woredas* (districts) was prepared to support scaling up of best practices in agricultural soil fertility and soil water management.

### **Sustainable Land Management and Land Degradation Neutrality**

#### *Preventing and remediating soil degradation through land care*

The EU-FP7 RECARE project, 'Preventing and remediating degradation of soils in Europe through land care', is aimed at developing effective prevention, remediation and restoration measures using an innovative trans-disciplinary approach. The project (2013-2018) focusses on 17 case studies, representing a range of soil threats in different biophysical and socio-economic environments across Europe. ISRIC is responsible for the work package on 'Selection of promising prevention, remediation and restoration measures' and we are also contributing to the work package on 'State of degradation and conservation' in the RECARE case study sites.

#### *Decision support for sustainable land management*

In 2016, we were approached by the WOCAT (World Overview of Conservation Approaches and Technologies) Secretariat to contribute to the development of a decision support framework

for sustainable land management (SLM). With CDE (Centre for Development and Environment, Berne) and GIZ (German Agency for International Cooperation), we further developed the modules on 'National/Subnational Level Assessment' and 'Landscape Level Assessment'; funding was provided by BMZ (Federal Ministry for Economic Cooperation and Development, Germany) through GIZ. The modules include stakeholder workshops, expert assessments, SLM data collection, mapping and analysis, and make use of WOCAT tools and methods such as the Global Database on SLM. The overall decision support framework is currently being applied in 15 countries by WOCAT.

### *Cost-effective tools to manage soil quality and function*

The aim of the EU Horizon2020-funded project on 'Interactive Soil Quality Assessment in Europe and China for Agricultural Productivity and Environmental Resilience' (ISQAPER, 2015-2020) is to develop a mobile phone app for interactive, in-field soil quality assessment and monitoring (SQAPP). ISRIC provided soil property data (SoilGrids) for zoning of pedo-climate and classification of agricultural systems in Europe and China. As part of the project, the effects of selected agricultural management practices on soil quality indicators were analysed. To do this, we first compiled a database of research results

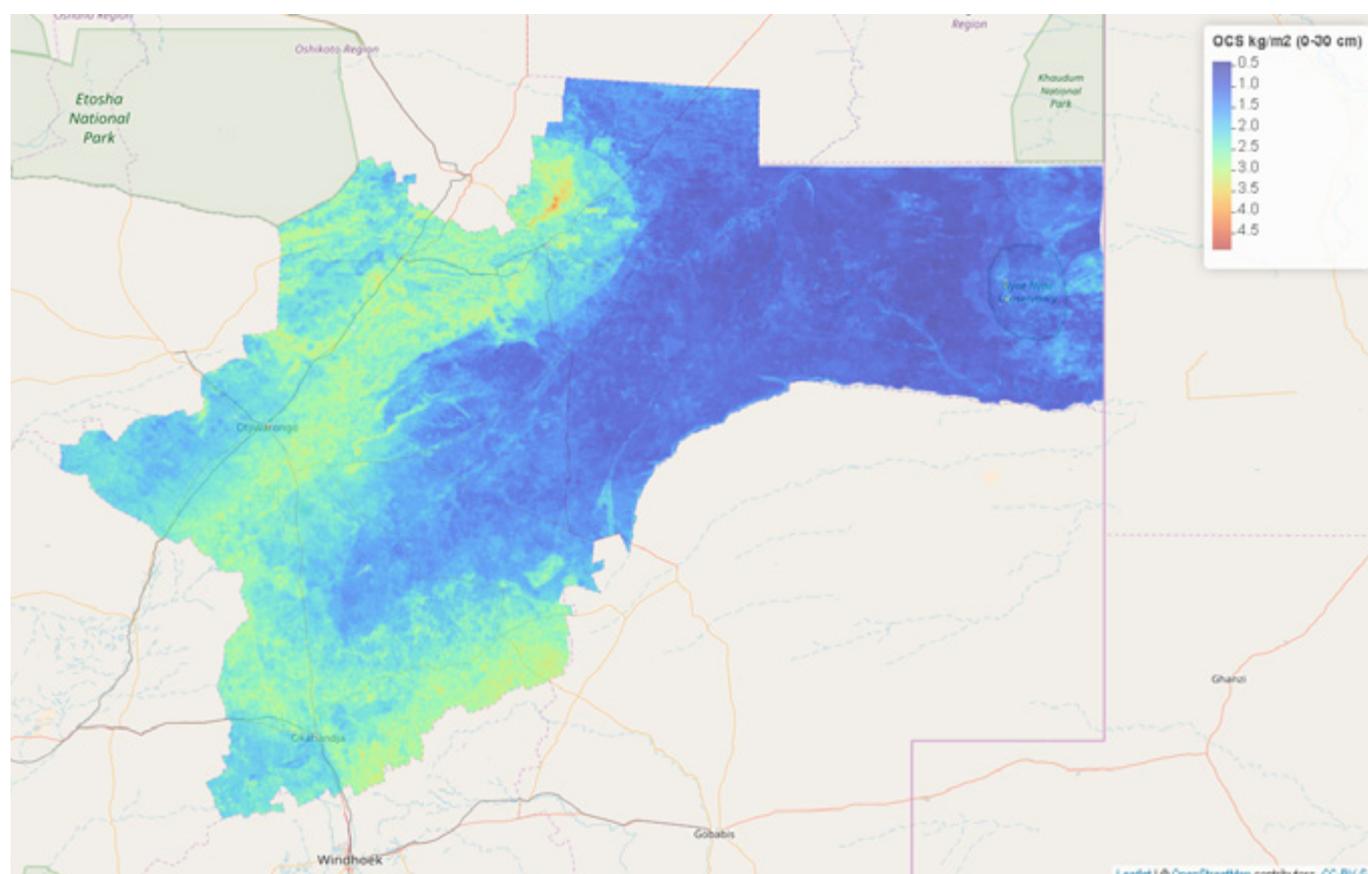
from long-term field experiments and carried out a literature review. The findings are being used to support the development of SQAPP. Once the interactive app has been fully developed (2018), it will be hosted by ISRIC as a joint product with Wageningen University.

### *Enhanced resilience of landscapes*

Mid-2017, we joined a 2-year collaboration project on 'Land Use Planning for Enhanced Resilience of Landscapes' in Madagascar. The World Bank funded project, led by Wageningen University, supports a process of integrated multi-sectoral decision making for national landscape management. The first mapping workshop is scheduled to take place in early 2018 in Antananarivo, to obtain a national spatial overview of land degradation and sustainable land management in the country.

### *UNCCD Global Land Outlook*

ISRIC provided expertise on soil and land degradation to supplement and contextualise modelling work of PBL. In particular, we contributed to the chapter on 'Projected changes in the condition of the land and future developments'.



SOC stocks for the Otjozondjupa region in Namibia derived from digital soil mapping

Elements thereof were used to support a key chapter in the 2017 UNCCD Global Land Outlook.

### *Marginal lands for growing industrial crops*

We contributed to the characterisation and analysis of projections for current and future marginal lands in Europe facing natural constraints. The analysis will serve as a basis for developing sustainable best-practice options for industrial crops in Europe. The work was sub-contracted by Wageningen Environmental Research, as part of a larger EU H2020-project coordinated by the Centre for Renewable Energy Sources and Saving Foundation (Greece).

## **Mitigation and adaptation to climate change**

### *Towards space-time modelling of SOC changes*

Since COP21 in Paris (December 2015), research on soil organic carbon (SOC) dynamics features more prominently on the international agenda. Judicious management of SOC, held in soil organic matter, is important for agronomy, land conservation and rehabilitation, soil water management, mitigation of greenhouse gas emissions and adaptation to climate change. Within this setting, there is an increasing interest in approaches that can be used to measure and model changes in SOC stocks over time.

ISRIC developed and tested a spatio-temporal model, using SoilGrids and a comprehensive set of environmental co-variables. Limitations, challenges and opportunities of this novel methodology were presented during the second Global Soil Security Conference in Paris (5-6 December 2016). Once fully tested, the SoilGrids-based spatio-temporal model may be used, for example, in support of the French '4-pour-mille' initiative and UNCCD's Land Degradation Neutrality work and similar sustainable land management initiatives at the global and regional level.

### *International research cooperation on soil organic carbon sequestration*

CIRCASA, an abbreviation for 'Coordination of International Research Cooperation on Soil Carbon Sequestration in Agriculture', is a 7-year project funded by the EU H2020-programme. The overarching goal of the multi-partner project, launched in November 2017, is to develop international synergies concerning research and knowledge exchange in the field of carbon sequestration in agricultural soils at European Union and global levels with active engagement of key stakeholders. ISRIC's contributions focus on setting up a knowledge and information system and supporting

the literature review on carbon sequestration in agriculture. Ultimately, the project deliverables will be integrated into the CIRCASA Online Collaborative Platform by the consortium.

### *Mapping of potential SOC stocks*

In collaboration with the Woods Hole Research Centre (USA), we produced global maps of potential SOC stocks using the SoilGrids framework. The GIS layers were compared with existing maps of actual soil carbon stocks to identify areas where opportunities exist for additional storage of organic carbon in the soil. This knowledge is important, as land use and agriculture in particular have led to dramatic decreases in SOC stocks during the past decades, with concomitant emissions of greenhouse gases, thus exacerbating climate change. The project quantified the historic SOC loss over the last 12,000 years, using state-of-the-art data sets and methods. Results were published in PNAS in 2017.

### *Baseline SOC stock mapping in Namibia*

CIAT contracted ISRIC to develop SOC maps for two LDN-pilot regions in Namibia. This involved the development of a tutorial and subsequent training of local researchers in digital soil mapping in Windhoek. Training focussed primarily on mapping SOC baselines for the Otjozondjupa and Omusati region in support of ongoing integrated regional land use plans. As of 2018, local experts will use the newly-gained expertise to map SOC baselines, and changes therein upon changes in land use, in other regions of Namibia. SOC stock change is one of the three sub-indicators in the UNCCD LDN reporting.

# Reference collections

## World soil museum

The ISRIC World Soil Museum in Wageningen, with its display of some 80 monoliths from all over the world, provides the foundation for our activities and programmes on education, research, collection and documentation. Since the opening of the new museum on the Wageningen campus in 2014, we have had some 2450 visitors each year, up from around 750 a decade ago.

Our core group of returning visitors consists of university students from Germany and Belgium. Further, numerous students attending Dutch universities (Wageningen and Amsterdam) regularly 'drop-in' and the range of visitors from Dutch colleges and vocational education and training programmes continues to increase. Main areas of specialisation and interest of these groups were forest management, applied biology and land and water management.

An encouraging development for us has been the increasing number of primary and secondary schools that visit the museum, a clear reflection of the breadth of the museum's educational programme. To support this programme we developed a set of 'soil stories' in which selected soil monoliths are explained in a societal, historical and/or

environmental context. This approach can be tailored to the level and interest of each group.

ISRIC has launched the virtual World Soil Museum in 2016, making its collections more widely accessible to the world. For example, in 2017 the virtual museum was used to discuss soils and their properties with school children from Concordia International School in Hanoi, Vietnam.

## Soil reference library

ISRIC maintains a repository for 'endangered' documents on soil resources. Main activities undertaken during the period under review were the scanning of reports and maps as well as the consolidation of our library holdings, which included the removal of some redundant materials. In December 2017, the collection consisted of some 9,140 soil-related maps, of which 87% have been digitised, and some 16,180 reports of which some 37% are available online in full-text format.

The library holdings provide a valuable source of soil point and map data for consideration in WoSIS and other projects. Further, there is a steady demand from all parts of the world for the scanned materials held in the online library.



*Guided tour through the physical World Soil Museum*



Participants and lecturers of the annual Spring School (2017)

## Training and education programme

The ISRIC Spring School was attended by participants from 29 countries in 2016 and 39 countries in 2017. The main purpose of the annual course is to introduce participants to the soils of the world, soil databases, software for soil data analysis and visualisation, digital soil mapping and soil-web services. Participants included MSc and PhD students, soil and environmental scientists, and professionals in natural

resources management planning. By its very nature, the Spring School provides a solid foundation for continued international collaboration and exchange of information.

The Spring School also contributes to the implementation of the Global Soil Partnership. It is organised under the auspices of the C.T. de Wit Graduate School for Production Ecology and Resource Conservation of Wageningen University. In 2016 and 2017, we had guest lecturers from the Catholic University of Leuven (Belgium) and the Soil Biology and Biological Soil Quality Group of Wageningen University.

## Guest researchers, thesis students and internships

We welcomed four guest researchers from Canada, Cameroon, the Netherlands and the USA in 2016/2017. The main objectives of their respective research were to gain practical experience

in working with digital soil mapping and data handling, and to discuss options for project-based collaboration.

ISRIC staff supervised three MSc thesis and two PhD thesis students (from Argentina and the Netherlands). One recent MSc graduate from Wageningen University was provided the opportunity to gain work experience in an academic environment in the framework of the iSQAPER project.

We are grateful to our five volunteers for their continued inputs to the Library, Museum and Data project respectively.

## Website

The website is crucial for our information dissemination strategy. Mid-2015, we started conceptualising a new corporate website aimed at better serving the needs of users of soil information around the globe. In 2016, we started building the new website. Following the development and testing stage, the new website was launched in April 2017. It includes an improved data download centre (soil data hub) and provides improved guidance for professionals from a wide range of disciplines. The re-design of the website also looked at how new clients, such as policy and decision-makers, or people from the private sector can be better targeted and served with quality-controlled soil information.

## Staff

ISRIC has a staff complement of 16.2 FTE (full time equivalent). Our colleague Ad van Oostrum (soil analytical methods expert) retired in 2016 after 46-year of service; we gratefully acknowledge his continued contributions as a guest-researcher. Two staff members left the centre to pursue their career elsewhere in 2016 and our ranks were strengthened by colleagues with expertise in soil-sensing and external relations. Further, in 2017, our team expanded to include an expert in web services and geo-computation and an expert in sustainable land management.

A landmark event for ISRIC was the appointment of Dr Gerard Heuvelink as Professor in 'Pedometrics and Digital Soil Mapping' by the Executive Board of Wageningen University & Research (June 2017). The professorship by special appointment is funded by ISRIC. Academically, it is positioned within the chair group on Soil Geography and Landscape. The appointment of Professor Heuvelink further strengthens the research and teaching collaboration between ISRIC and Wageningen University.

Two new Board members were appointed in 2016; we gratefully thank the outgoing Board Members for their guidance.

## Membership of editorial boards

In recognition of their expertise, five staff members are Associate Editors (*European Journal of Soil Science*; *Spatial Statistics*) and/or Editorial Board members of one or more Scientific Journals: *Agriculture, Ecosystems and Environment*; *Environmental and Ecological Statistics*; *Frontiers in Environmental Science (Environmental Informatics section)*; *Geoderma*; *Geoderma Regional*; *Geoinformation*; *Geographical Analysis*; *International Journal of Applied Earth Observations*; and, *Pastoralism Research, Policy and Practice*. In late 2017, ICSU-WDS invited the Head of WDC-Soils to join the 'CoreTrustSeal (Trustworthy Data Repositories) Assembly of Reviewers'.

## Awards and scientific recognitions

In 2016, Dr Gerard Heuvelink received a 'Founder's Award' from ISARA (International Spatial Accuracy Research Association) in recognition of his 'substantial and lasting contributions to the foundations of spatial accuracy'.

## Staff publications

ISRIC staff have contributed to a number of peer-reviewed and other publications on digital soil mapping, conventional soil mapping, and use of soil data in support of sustainable land management. Full references to these may be found on our website.

A co-authored publication that deserves special mention is 'Soil carbon debt of 12,000 years of human land use', which was published in PNAS in 2017. According to this study, the past 12,000 years of human land use have resulted in the loss of 116 Pg C (1 Pg =  $10^{15}$  g) from the soil, which is much more than assumed in earlier publications on the subject.



ISRIC – World Soil Information is an independent foundation with a mission to serve the international community with data about the world's soil resources to help addressing major global issues.

ISRIC was founded in 1966 following a recommendation of the International Society of Soil Science (ISSS) and a resolution of the United Nations Educational, Scientific and Cultural Organization (UNESCO). From its inception then it has been supported by the Netherlands Government. In 1989, ISRIC became the *World Data Centre for Soils*; since 2011 we are accredited as regular member of the ICSU World Data System.

ISRIC has a strategic association with Wageningen University & Research.

