

GLOSOLAN spectroscopy-I/20/Report



Food and Agriculture
Organization of the
United Nations



Report of the First Plenary Meeting on soil spectroscopy of the Global Soil Laboratory Network (GLOSOLAN)

Zoom, 23-35 September 2020

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**REPORT OF THE FIRST PLENARY MEETING ON SOIL
SPECTROSCOPY OF THE GLOBAL SOIL LABORATORY NETWORK
(GLOSOLAN)**

Zoom, 23-25 September 2020

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2020

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1. Introduction

The first plenary meeting on soil spectroscopy of the Global Soil Laboratory Network (GLOSOLAN) was virtually organized by the Global Soil Partnership (GSP) on 23-25 September 2020 on the online platform Zoom. See agenda in Annex I. The meeting was attended by approximately 340 participants from 63 countries (see list of participants in Annex II) and was opened by Mr. Ronald Vargas, GSP Secretary, and Ms. Nopmanee Suvannang, GLOSOLAN Chair. While delivering their opening remarks, Mr. Vargas and Ms. Suvannang recalled that GLOSOLAN was established in 2017 to build and strengthen the capacity of laboratories in soil analysis and to respond to the need for harmonization of soil analytical data. After three years of intense work on wet chemistry, GLOSOLAN decided to look into dry chemistry and officially launched its global initiative on soil spectroscopy in April 2020. Thanks to the support of a few institutions that believed in the potential of GLOSOLAN on soil spectroscopy, two concept notes on “A global soil spectral calibration library and estimation service” and on “Global capacity development in soil spectroscopy” were drafted and published on the GLOSOLAN webpage, which was lately upgraded (see [here](#)). These documents represent GLOSOLAN’s vision on how the initiative could help laboratories, countries, and regions to build their capacities in soil spectroscopy. These are proposals intended to open the discussion at the first plenary meeting on how we could move forward and to motivate countries, institutions, organizations, and top experts on the topic to join our initiative and, most importantly, to join efforts. It is in this spirit that the GSP organized this meeting, which was aimed to:

1. Define the work plan of GLOSOLAN on soil spectroscopy (main activities, timeline, and implementing partners) and especially on the establishment of a global soil spectral calibration library and the writing of guidelines, protocols, and manuals on soil spectroscopy;
2. Define how GLOSOLAN will interact with other initiatives and how projects can contribute to GLOSOLAN;
3. Define how GLOSOLAN will interact with countries and laboratories, institutions, and organizations; and
4. Define the governance of the initiative: working group, working group chairs, and regional champion laboratories/institutes on spectroscopy.

Ultimately, Mr. Vargas and Ms. Suvannang recalled the potential of this initiative for soil mapping, monitoring, sustainable soil management practice, and decision making at all levels. What GLOSOLAN is doing is not just for laboratories but is strictly connected to data management, soil management, and policy and to the capacity of countries to report on the Sustainable Development Goals.

The first day of the meeting was dedicated to introducing participants to soil spectroscopy and its possibilities and pitfalls, an overview of the status and needs in soil spectroscopy as determined from a questionnaire issued by GLOSOLAN earlier in the year, and the two concept notes as published on the GLOSOLAN website. Ultimately, particular attention was paid to the way in which decisions should be made within the GLOSOLAN initiative on soil spectroscopy.

2. Decision making procedure

The participants agreed to operate as per Figure 1. Countries and laboratories will provide inputs to the working group on spectroscopy for the drafting of documents and the development of tools and will review documents as needed. The working group will draft soil spectroscopy documents and send them to countries and laboratories for review. In this regard, countries, laboratories, and the working group will remain in continuous communication until the documents are finalized, which will be presented for endorsement at the plenary meeting on spectroscopy. Additional information on the tasks of the working group on soil spectroscopy are in the Terms of Reference in Annex III. It was decided that the plenary meeting on soil spectroscopy will be the highest decision-making body of the initiative, responsible for reviewing the proposals, documents, and tools made, written, and developed by the working group and for defining the yearly work plan of GLOSOLAN on soil spectroscopy. All GLOSOLAN members on soil spectroscopy and partners working on the topic are welcome to attend the plenary meeting. Ultimately, the working group leader(s), which are elected every two years (see Terms of Reference in Annex III), will report the outcomes of the plenary meeting on soil spectroscopy to the annual GLOSOLAN meetings.

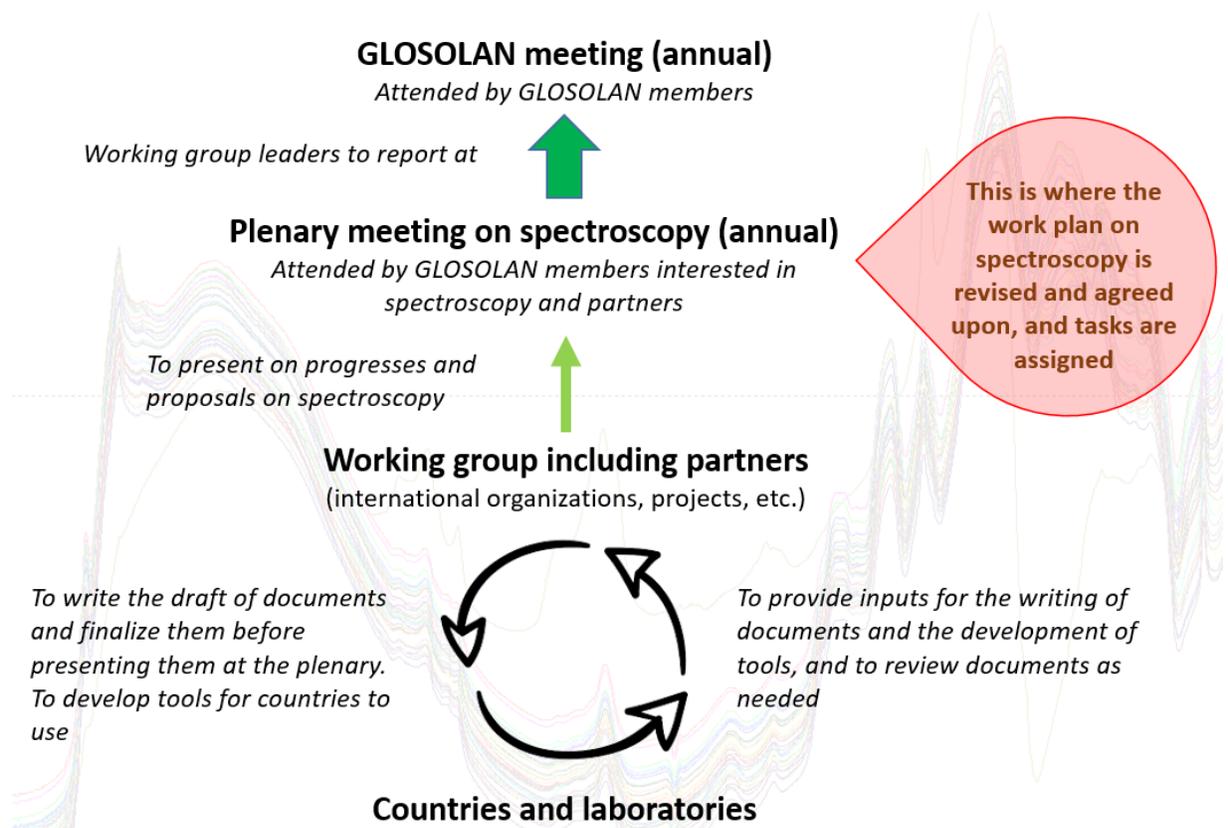


Figure 1. Operating procedures.

Following an election, working group leaders for the period 2020-2022 are Ms. Fenny van Egmond from ISRIC - World Soil Information (ISRIC), the Netherlands; Mr. Richard Ferguson from the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS); and Mr. Keith Shepherd

from World Agroforestry (ICRAF) and iSDA, Kenya. As per the request of the plenary, a short introduction to each of the elected leaders is herewith provided:

- Ms. Fenny van Egmond

Fenny van Egmond has worked as soil sensing specialist at ISRIC – World Soil Information and Wageningen Environmental Research since 2016. She has a background in soil science and GIS remote sensing and had previously worked for 12 years at small advisory and research companies applying different soil sensing techniques, such as gamma ray spectrometry, ground penetrating radar, X-Ray Fluorescence, etc. for various clients in (precision) agriculture, environment, archaeology, and road construction using a pragmatic and question oriented approach. At ISRIC she wrote a vision on sharing and serving soil spectral data for ISRIC and has been putting this into practice since. She also co-leads the work done by ISRIC on GLOSI, the Global Soil Information System being built by GSP Pillar 4, and the soil data exchange model and codelists that are needed for GLOSI and developed by Pillar 5. The GLOSI federated system of databases or nodes ensures owners full control of their data and encourages them to ‘map’ their data to a common format to enable exchange and (data) harmonisation. In her view, spectral data should be an integral part of GLOSI and data should be as accessible and FAIR as possible. GSP and GLOSOLAN are a very powerful network with a strong drive that connects the soil community globally and enables joint development towards a more soil aware and better informed world. Harmonised and high quality soil spectral information and tools can be a key to help solve local and global challenges by enabling better informed decisions. At Wageningen Environmental Research, she set up a soil MIR lab facility together with Titia Mulder and has started to build a Dutch Soil Spectral Library.

- Mr. Richard Ferguson

Since, 2002, Rich Ferguson has served as an analytical chemist and team leader with the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil and Plant Science Division (SPSD). Rich is located at the National Soil Survey Center, Kellogg Soil Survey Laboratory (KSSL), in Lincoln, Nebraska. Prior to working at the KSSL, Rich worked at the École Polytechnique Fédérale de Lausanne (Switzerland) followed by the United States Department of Defense. Rich’s professional background includes work in catalysis, synthesis, biological model compounds, photonics, analysis, and chemometrics. Since 2011, Rich has led the KSSL mid infrared (MIR) data collection program that was inspired by ground-breaking work, largely done outside of the USA, that established using MIR to estimate soil properties. Rich is part of an NRCS-SPSD team that, in consultation with global specialists, is dedicated to enabling routine use of MIR soil spectrometry by NRCS field offices for soil classification, interpretation, assessment, and monitoring. Rich has co-authored methods and papers on the topic of MIR spectrometry and views FAO GSP-GLOSOLAN as a needed and compelling platform for stakeholders worldwide to do progressive, organized science together on the topic; Rich believes that cooperation among specialists in the field, combined with strong educational outreach and organizational support systems, can help to make soil spectrometry an everyday, reliable tool at a global scale.

- Keith Shepherd

Keith Shepherd has worked on soil spectroscopy for over 20 years. In 2007, he published a vision on the value of application of infrared spectroscopy in agricultural and environmental management for developing countries (*J. Near Infrared Spectrosc.* 15, 1–19) and has spent the latter half of his career working to achieve that vision. He established the World Agroforestry (ICRAF) Soil-Plant Spectral Diagnostic Laboratory in Nairobi, which has developed protocols for soil analysis using VNIR, FT-NIR, FT-MIR, total reflection and portable x-ray fluorescence spectroscopy, and laser diffraction particle size analysis. The ICRAF lab team has helped establish 30 spectral labs in 17 African countries, as well as in China, India, Peru, Poland, UK, and USA. Keith is a co-founder of the Africa Soil Information Service (AfSIS), which helped four African countries develop national soil information systems based on spectral technology and established the first statistical sampling frame and digital soil property maps of Africa. At ICRAF, he has established a spectral library of over 150,000 samples and physical soil archive and contributed to several global spectral libraries. He has contributed to the design of the first open-source, full NIR range handheld spectrometer. Keith has co-led the development of the GLOSOLAN Global Spectral Calibration Library and Estimation Service initiative and associated guidelines and capacity development. Keith is now a Senior Research Fellow at ICRAF and is Head of Diagnostics and Decision Science at Innovative Solutions for Decision Agriculture (iSDA), which aims to provide sustainable digital advisory services to smallholder farmers in sub-Saharan Africa and South Asia.

The work of GLOSOLAN on spectroscopy will be facilitated by the GSP through the GLOSOLAN coordinator, who will assist in the development and implementation of the GLOSOLAN work plan on spectroscopy, support the working groups, stimulate communication between stakeholders, and ensure adherence to decision-making procedures.

3. Global Soil Spectral Calibration Library

The second day of the meeting was dedicated to discussing how to establish the global soil spectral calibration library, one of the milestones of the initiative of GLOSOLAN on soil spectroscopy. Ms. Lucrezia Caon (GLOSOLAN Coordinator, GSP Secretariat) presented the proposal contained in the concept note “A global soil spectral calibration library and estimation service” (see figures 2 and 3) with the support of Mr. Richard Ferguson.

Original Proposal

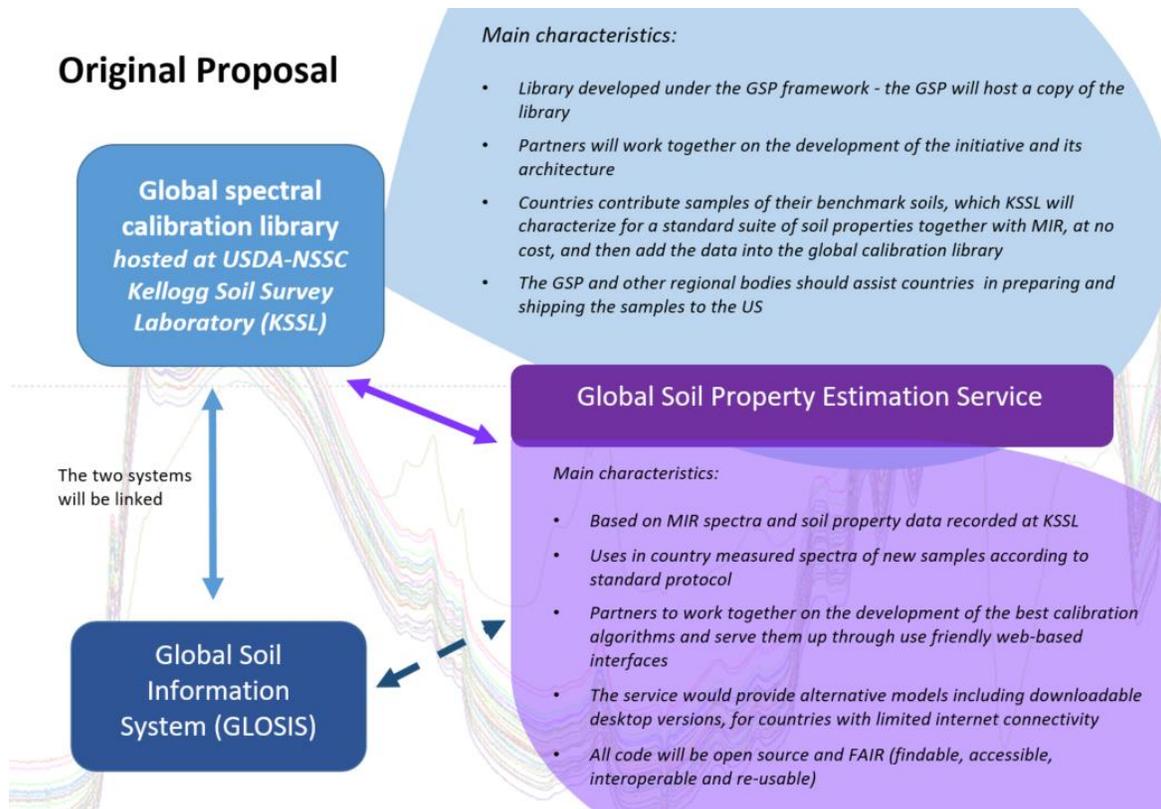


Figure 2. Main characteristics of the global soil spectral calibration library in the concept note “A global soil spectral calibration library and estimation service.”

Original Proposal

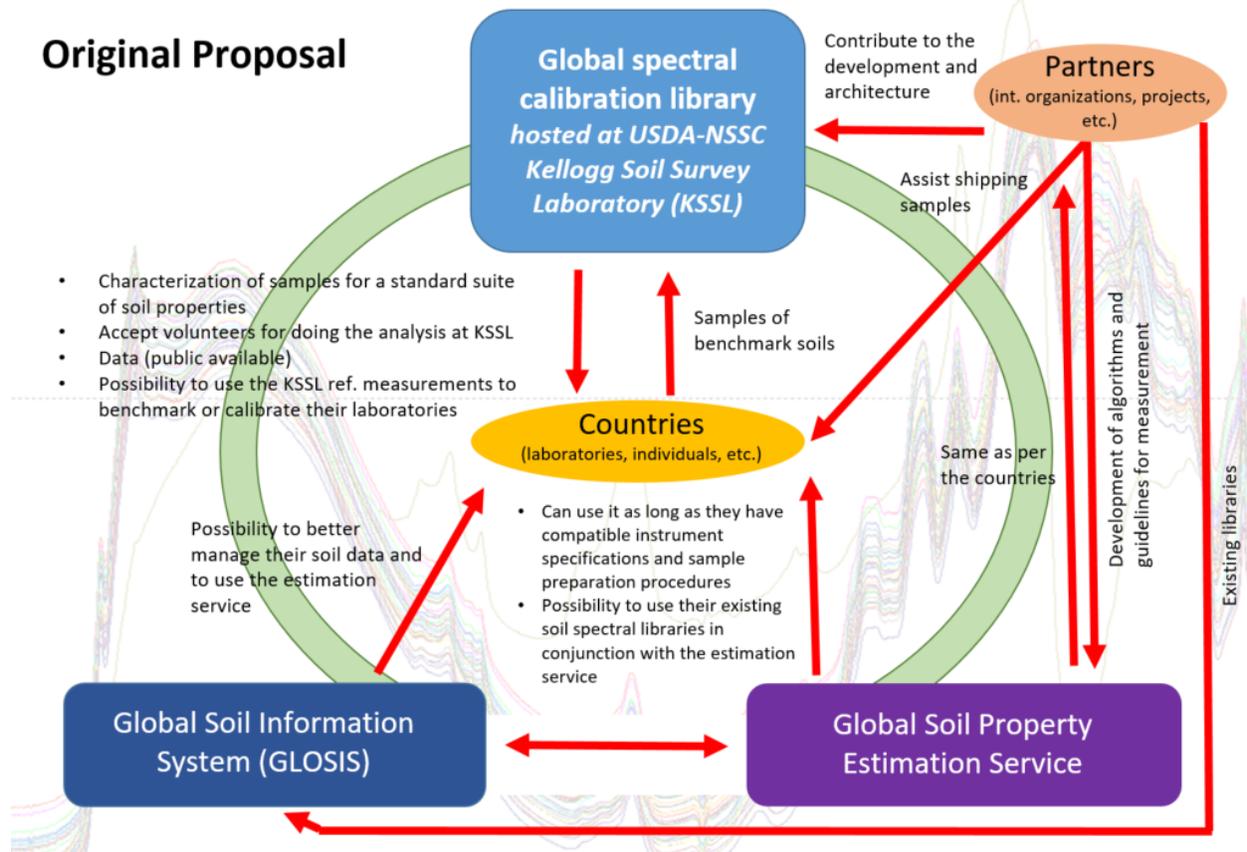


Figure 1. Organization of work according to the concept note "A global soil spectral calibration library and estimation service."

Mr. Ferguson explained why it was proposed to establish the library at the USDA, focusing on the following main aspects:

- The USDA-NRCS Kellogg Soil Survey Laboratory (KSSL) maintains a large and growing library of mid-infrared (MIR) spectra of soils. They have over 80,000 archived samples MIR scanned since 2011, allowing calibrations at useful scales. Data collection is modelled after protocols by Shepherd (ICRAF-CGIAR);
- Kellogg Soil Survey Laboratory has more than 400,000 archived samples for calibrating at various scales;
- There is no fee to sample submitters for USDA-NRCS KSSL analytical services or data under this project (currently limited to 300 samples per country, doing the spectral and conventional measurements listed in the sample submission guidelines);
- Data will be published online for free (open access policy);
- For the GLOSOLAN MIR spectroscopy initiative, in addition to mid-infrared (MIR) spectra, the soil properties that the KSSL will measure under this initiative are reported in table 1. Except as noted with an asterisk (* to-be-published in v. 6 of SSIR-42; write-up available on request to: christopher.lee@usda.gov), method codes are from "[Kellogg Soil Survey Laboratory Methods Manual, SSIR-42, v. 5, USDA-NRCS.](#)"

Table 1. Soil properties that the KSSL will measure under this initiative

Soil property	Method
Total carbon, nitrogen, and sulfur	method 4H2a1-3a1
Inorganic carbon (if appropriate)	method 4E1a1a1a1-2
Organic carbon (calculated from total carbon and inorganic carbon)	methods 4H2a + 4E1a1a1a1-2
Gypsum	method 4E2b1a1a1-2
pH: 1 : 1 water	method 4C1a2a1a-b1
pH: 1 : 2 0.01-M calcium chloride	method 4C1a2a2a-b1
pH: 1 : 1 1-N potassium chloride	method C1a2a3a-b1
pH: 1 : 50 1-N sodium fluoride (if appropriate)	method 4C1a1a1a-b1
Electrical conductivity	method 4F1a1a1a1
Sodium adsorption ratio and exchangeable sodium percentage (derived quantities)	methods 4F3b + 4F3a2
Cation exchange capacity, pH 7	method 4B1a1a1a1a-b1
Ammonium acetate (pH7) exchangeable calcium, magnesium, potassium, sodium	method 4B1a1c1-4a-b1*
1500 kPa water holding capacity	method 3C2a1a-b
Dithionite-citrate extractable iron, aluminum	method 4G1b1-4a-b1*
Ammonium oxalate extractable iron, aluminum	method G2a1a1-5a-b1
Clay, silt, sand	method 3A1a1a
Exchangeable aluminum	method 4B3b1a1-b1*
Mehlich III phosphorus	method 4D6a1a-b1
Olsen phosphorous (if appropriate)	method 4D5a1a-b1

The USDA will provide completed metadata (e.g., origin of samples, submitting entity, etc.), but does not require an author to cite the KSSL or acknowledge any contributor. If an author wishes to make an acknowledgment, the following citation can be used “Data are from the USDA NRCS SPSD National Soil Survey Center – Kellogg Soil Survey Laboratory”. However, GLOSOLAN strongly encourages all users of the library to acknowledge the KSSL and the institutions from which the samples originated.

Contributors are asked to review their data before it is made public. During the review, if a contributor has questions about data quality, sample re-analyses may be done. Once the data are certified; they are made

public. The measured data are available online at <https://ncsslabdatamart.sc.egov.usda.gov/>. Currently, spectral data are served via a portable memory drive or via CloudVault transfer, but a web based spectral data publication system is under development.

As the proposal contained in the concept note “A global soil spectral calibration library and estimation service” generated concerns and questions among participants and potential users of the library¹, Ms. Caon presented a revised version of the original proposal that considers the library established as a federated system (see figures 4 and 5). A federated system is a network of nodes or instances (for instance a lab database or soil information system) that are connected via the internet using (internationally) agreed standards. The nodes can exchange information and data through this network, and can be accessed or queried through a (common) portal. All data remain on their own node, thereby keeping the nodes in control of the data. In this regard, Ms. Fenny van Egmond presented the Global Soil Information System (GLOSIS), a federated system under development within the GSP that can be connected to the global soil spectral calibration library.

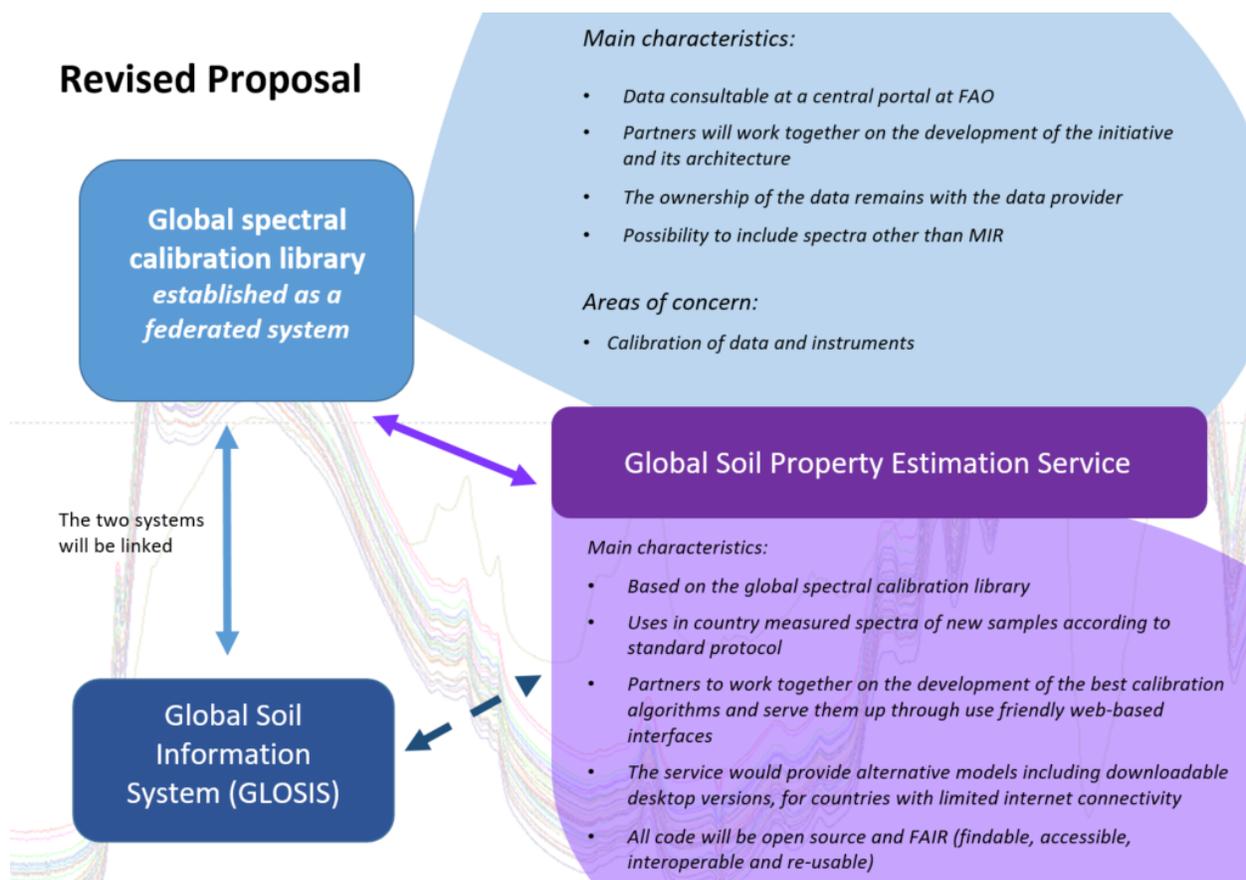


Figure 2. Main characteristics of the global soil spectral calibration library according to the revised proposal.

¹ When the organization of the plenary meeting was announced, Ms. Caon (GLOSOLAN coordinator) asked all GLOSOLAN members and partners on soil spectroscopy to share their concerns, remarks, and questions regarding the proposal for the establishment of a global soil spectral calibration library. These were compiled and discussed by the working group on soil spectroscopy which formulated an alternative proposal.

Revised Proposal

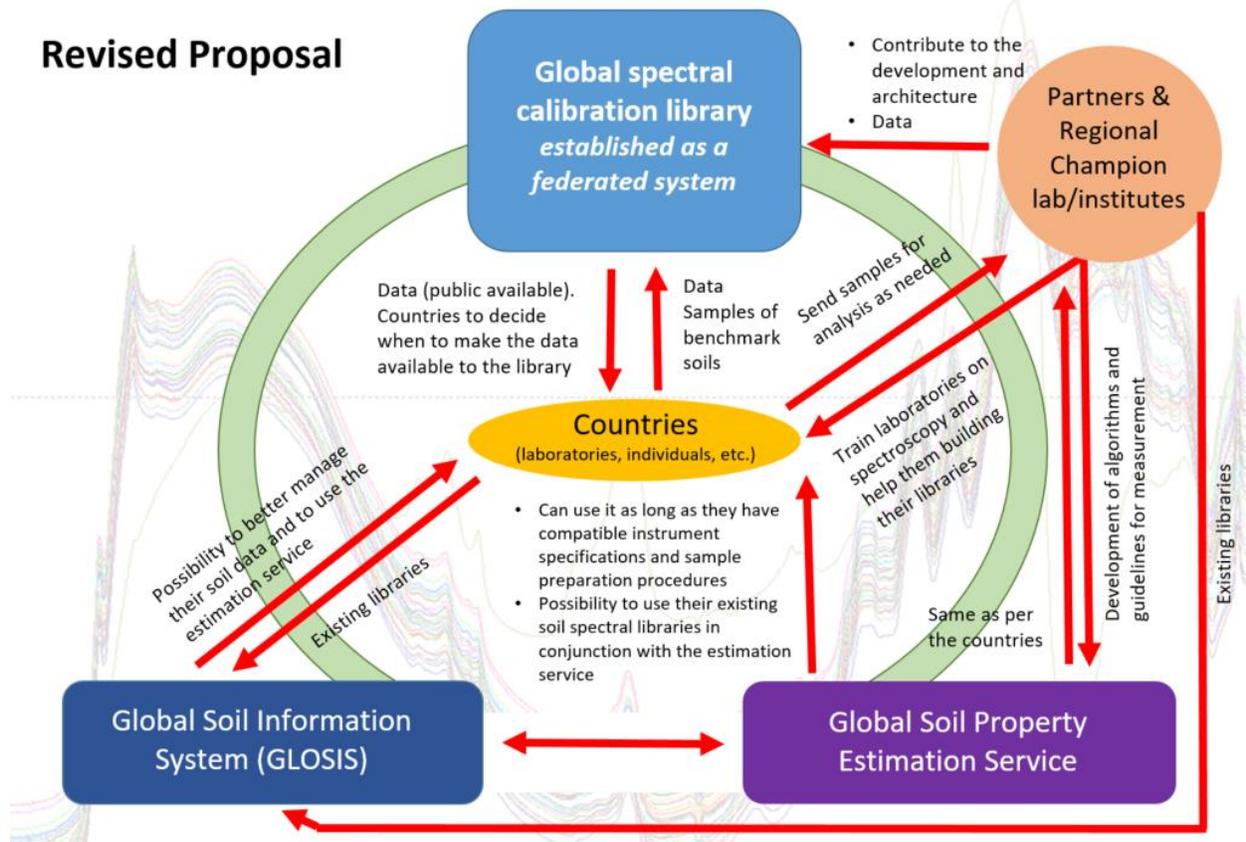


Figure 3. Organization of work according to the revised proposal on the establishment of the global soil spectral calibration library

This proposal foresees the development of the library in two stages.

STAGE 1: Establishment of the MIR library and a calibration service based on KSSL instruments. Estimated duration: two years.

During the implementation of stage 1, GLOSOLAN will focus only on MIR and the federated system is not yet to be in place. The main activities related to the implementation of this stage are:

- Laboratories that accept the USDA open data policy can send subsets of their samples to the United States
- Laboratories that do not accept the USDA open data policy can work on their own or with their regional champion laboratory/institute and contribute to GLOSOLAN guidelines, protocols, etc.
- First version of spectral measurement protocols for MIR in laboratories is issued
- GLOSOLAN (GSP/FAO and partners) will start building the federated system
- GLOSOLAN (GSP/FAO and partners) will start working on calibration and calibration transfer

STAGE 2: Inclusion of other spectrometers and spectral data in the library and establishment of the necessary calibration

During stage 2, GLOSOLAN will work on different spectra (MIR, NIR, VNIR, etc.) and the federated system will be in place. The main activities related to the implementation of this stage are:

- Laboratories continue to send samples to the KSSL or to their regional champion laboratory/institute or continue to analyze the samples by their own means and build up their own spectral libraries, preferably using standard protocols
- GLOSIS provides access to different spectral libraries
- GLOSOLAN (GSP/FAO and partners) continues to work on calibration and calibration transfer

Sample providers can be acknowledged in the library (for publishing purposes).

Laboratories can contribute and use the global soil spectral calibration library as reported in table 2.

Table 2. Contribution and benefits that different types of laboratories can obtain by contributing to the establishment of the global soil spectral calibration library

Type of lab	How they can contribute	What they get back (added value)	Notes
Laboratories already using spectroscopy equipment that also do wet chemistry	<p>They can contribute with their own spectral library and a subset of their samples</p> <p>They can scan samples for others in the region</p> <p>Contribute to the development of standards and models</p>	<p>They can get more spectra for improving their calibration</p> <p>They can get models for building or strengthening their calibration</p> <p>Common publications</p> <p>Free alignment of instruments on spectroscopy and wet chemistry (PT costs to be covered by the initiative)</p>	<p>Attention: the equipment and range of spectrum should be compatible with the guidelines (guidelines to be prepared)</p>
Laboratories that are using spectroscopy equipment but DO NOT DO wet chemistry	<p>They can contribute with their own spectral library</p> <p>They can scan samples for others in the region</p> <p>Contribute to the development of standards and models</p>	<p>Use the calibration service</p> <p>Common publications</p> <p>Free alignment of instruments on spectroscopy</p>	<p>Attention: the equipment and range of spectrum should be compatible with the guidelines (guidelines to be prepared)</p>
Laboratories that just got to use spectroscopy equipment	<p>Send soil samples to the KSSL</p> <p>They can scan samples for others in the region to start building their own spectral library that can contribute to the global one later on</p> <p>Contribute to the development of standards and models</p>	<p>Use the calibration service</p> <p>Comparison of the results obtained by KSSL with their own</p> <p>Capacity building</p> <p>Common publications</p> <p>Free alignment of instruments on spectroscopy and wet chemistry (PT costs to be covered by the initiative)</p>	<p>Attention: the equipment and range of spectrum should be compatible with the guidelines (guidelines to be prepared)</p>
Laboratories that do not have spectroscopy equipment	<p>Send soil samples to the KSSL</p> <p>Contribute to the development of standards and models</p>	<p>Get their samples scanned by the KSSL or another laboratory (see above)</p> <p>Use of the calibration service</p> <p>Common publications</p> <p>Guidance on how to implement the spectroscopy analysis (they can start approaching the technology)</p>	

3.1. Decision making on the establishment of the global soil spectral calibration library

During the discussion, participants were asked which proposal they preferred: original or revised. As the majority of participants preferred the revised proposal, it was decided to establish the global soil spectral calibration library as a federated system. The participants also agreed to organize the work according to the two stages previously described and approved the main characteristics of the system as reported in Figure 4. They also approved the proposal to identify regional champion laboratories to support the implementation of GLOSOLAN activities on soil spectroscopy at national and regional level.

A trouble shooting exercise was done per each component of the system reported in Figure 4.

- **Interaction between countries, including laboratories and individuals, and the global soil spectral calibration library (see Figure 6)**

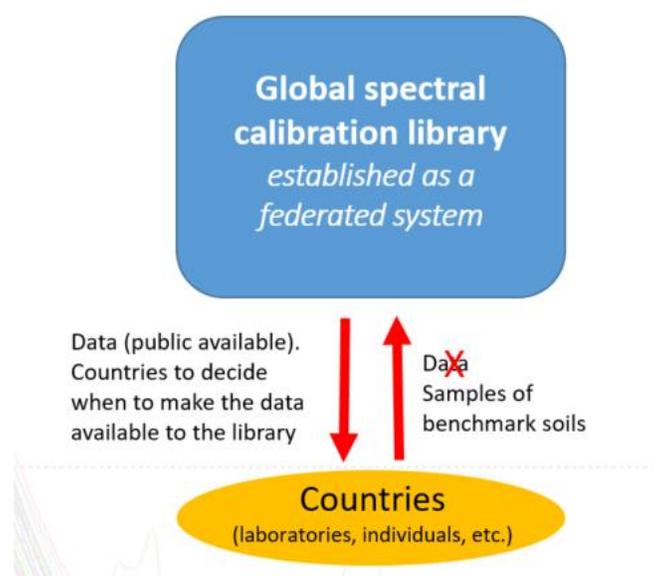


Figure 6. Interaction between the global soil spectral calibration library and countries

It was decided that countries will contribute to the library through the submission of samples of benchmark soils to the KSSL in stage 1 (or to their qualified² regional champion laboratories in stage 2). Qualified laboratories can provide data through GLOSIS. In return, countries will be able to use the data from the library, which each country can decide to make available.

Points of attention:

- Possibility to work with spectra other than MIR: GLOSOLAN will work on MIR during stage 1 but will extend its work to NIR, Vis-NIR, SWIR, gamma and XRF, EDXRF, FTIR, ATR during stage 2.
- Who will own the copyright of the global soil spectral calibration library? The FAO Global Soil Partnership will hold the copyright for the global product portal, but the data providers are and remain the owners of the data. For additional information, please refer to the [GSP Soil Data Policy](#).

² Qualified means that they succeeded in GLOSOLAN proficiency testing initiatives

Please note that all participants were invited to review the GSP Soil Data Policy and to inform the GLOSOLAN Coordinator, Ms. Caon, if any amendments to the document are needed. In this case, GLOSOLAN will prepare an amendment to be submitted to the attention of the Ninth GSP Plenary Assembly in June 2021.

- Who will bear the costs of shipping and analysis of soil samples to the KSSL and other regional champion laboratories? GLOSOLAN will apply for projects to cover these costs. Countries and regional champions are invited to cover these costs themselves as much as possible.
- Publication of data for samples sent to the KSSL: the data will be certified and made available as soon as the sample submitter has declared the data to be valid. The procedure adopted by the KSSL is the following: (1) the samples arrive at the KSSL, (2) the samples are analysed, (3) the results are sent back to the sample provider for review, (4) the results are confirmed by the sample provider, and (5) the data are published online. However, the review period cannot be unlimited. After participating in an online poll, participants express the need to have, on average, three months to review the data generated at the KSSL. This request was brought to the attention of the KSSL, which confirmed their availability to give samples providers such period of time.
- Publication of data for samples sent to regional champion laboratories other than the KSSL: the data will be certified and made available on the library as soon as their quality is approved. In this regard, the laboratories must agree on standards for quality control. In this case, the following procedure will be implemented:
 1. Identify regional champion laboratories;
 2. Ask the regional champion laboratories to provide information on methods and instruments as well as soil samples preparation protocols;
 3. Harmonize methods for wet chemistry (be careful not to duplicate or go against the work of GLOSOLAN on wet chemistry) and spectroscopy;
 4. Organize a proficiency test (PT) among KSSL and other regional champion laboratories in order to assess the variability of the measurements. There is no need for a minimum number of laboratories to participate in the PT since the results will be compared with those of the KSSL that will be considered as reference values;
 5. Work to reduce the variability of results through the organization of other PTs and capacity building activities;
 6. Establish a panel to oversee the approval process;
 7. Ask countries to send samples to qualified regional champion laboratories if they cannot, or do not want to, ship to the KSSL and start adding data to the library. In the library, it is important to report which laboratory carried out the analysis and where the samples came from.
- Publication of data for samples analysed by laboratories other than the regional champions (self-analysis): Individuals should send samples to their regional champion laboratories, which will help them to build their own soil spectral calibration libraries and obtain good quality data (software development at the point of data capture). GLOSOLAN will provide individuals with quality standards and organize PTs so that they can check the quality of their data themselves. In addition,

GLOSOLAN, with the support of the regional champion laboratories, will invest in capacity building to help those in need to improve.

Data produced by laboratories other than the regional champions cannot be considered in the modelling system.

The USDA, the regional champion laboratories, and FAO cannot take any responsibility for what the end users of the library publish. In this regard, GLOSOLAN relies on their professionalism and code-of-conduct.

As a follow-up to the meeting, the GLOSOLAN Coordinator will ask GLOSOLAN members if they are willing to contribute to this initiative by sending samples either to the KSSL or to another regional champion laboratory. Information will also be collected on those who are willing to do the analysis themselves, as well as information on the spectral range they measure and the presence of spectral libraries.

- **Interaction between partners on soil spectroscopy and regional champion laboratories, and the global soil spectral calibration library and countries (see Figure 7)**

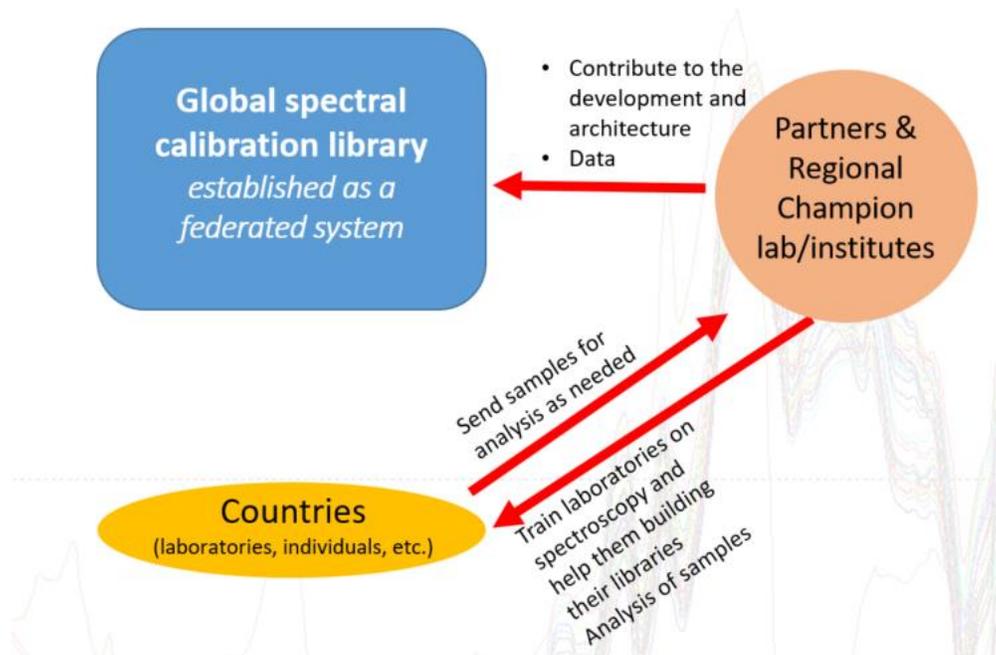


Figure 7. Interactions among partners, regional champions, and countries.

It was decided that countries will send samples of benchmark soils to the KSSL (or to qualified regional champion laboratories for analysis in stage 2). In return, the regional champion laboratories will train the laboratories on soil spectroscopy and assist them in building up their libraries while providing them with the results of the analysis for the soil samples they have received.

The partners and regional champion laboratories will contribute to the development and architecture of the global soil spectral calibration library and provide it with data. In return, they will be able to access and

use the data in the library. The regional champion laboratories can also identify the soils missing in the KSSL library and help fill these gaps. It should be noted that the KSSL uses the USDA system for soil taxonomy.

Points of attention:

- How can partners contribute to the development and architecture of the library? A dedicated working group will be established. All those interested in contributing to the development of the library should send an email to the GLOSOLAN coordinator at lucrezia.caon@fao.org. Ms. van Egmond will lead the working group and provide the list of software pieces to be developed. The tasks related to the development of the library will be assigned to the partners at the working group meetings.
- Who will bear the costs of training and remote support for laboratories in need? GLOSOLAN will apply for projects, but in-kind contributions are welcome.

➤ Interactions with the global soil property estimation service (see Figure 8)

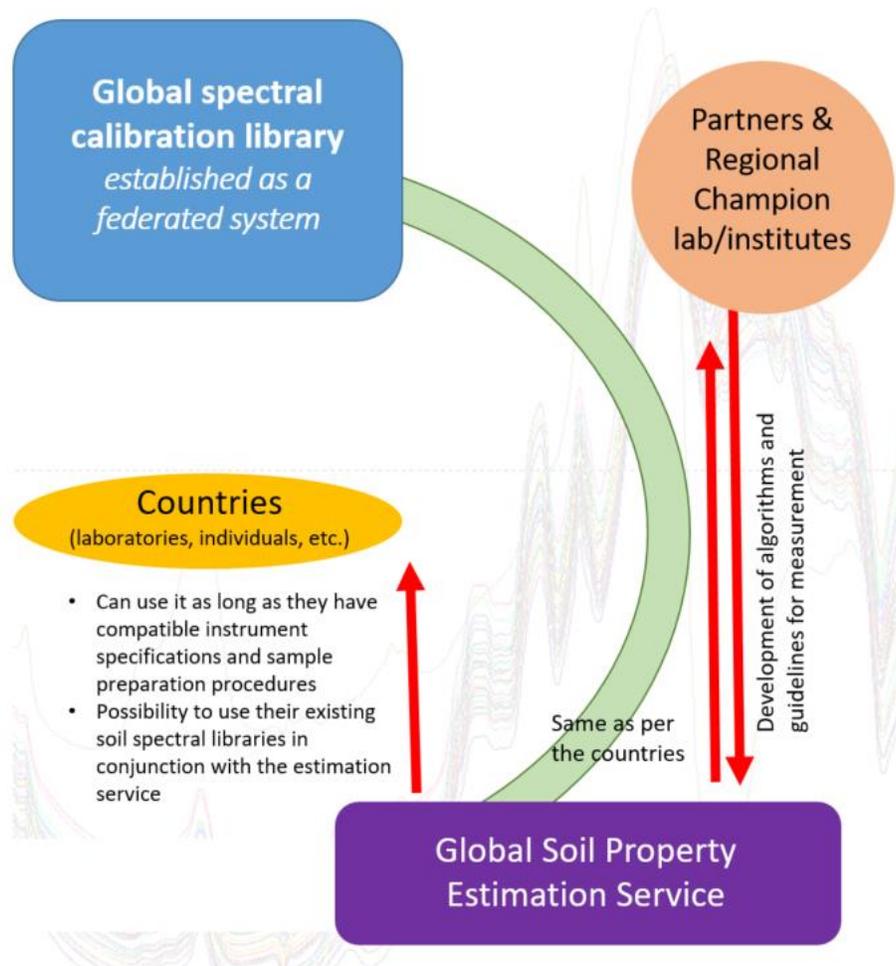


Figure 8. Interactions with Global Soil Property Estimation Service.

The global soil spectral calibration library will be connected to the global soil property estimation service. Soil spectroscopy partners and regional champion laboratories can contribute to the development of algorithms and guidelines for the measurement of the estimation service. In return, countries, soil spectroscopy partners, and regional champion laboratories will have the possibility to use the estimation service as long as they have compatible instrument specifications and sample preparation procedures. They could also use their existing soil spectral libraries in conjunction with the estimation service.

Points of attention:

- How can partners contribute to the development of algorithms and measurement guidelines? A dedicated working group will be established. All those interested in contributing to the development of the estimation service should send an email to the GLOSOLAN coordinator at lucrezia.caon@fao.org. Please note that the development of the algorithms is linked to the development of the software system and the discussion of the models.
- How will the connection between the library and the estimation service be made? This is a question to be discussed and dealt with by the working group on the estimation service and the library.
- Where will the estimation service be hosted? At FAO.
- How can compatible instrument specifications and sample preparation procedures be defined? Please look at section 4 of this report.

➤ **Interactions with the Global Soil Information System (GLOSIS) (see Figure 9)**

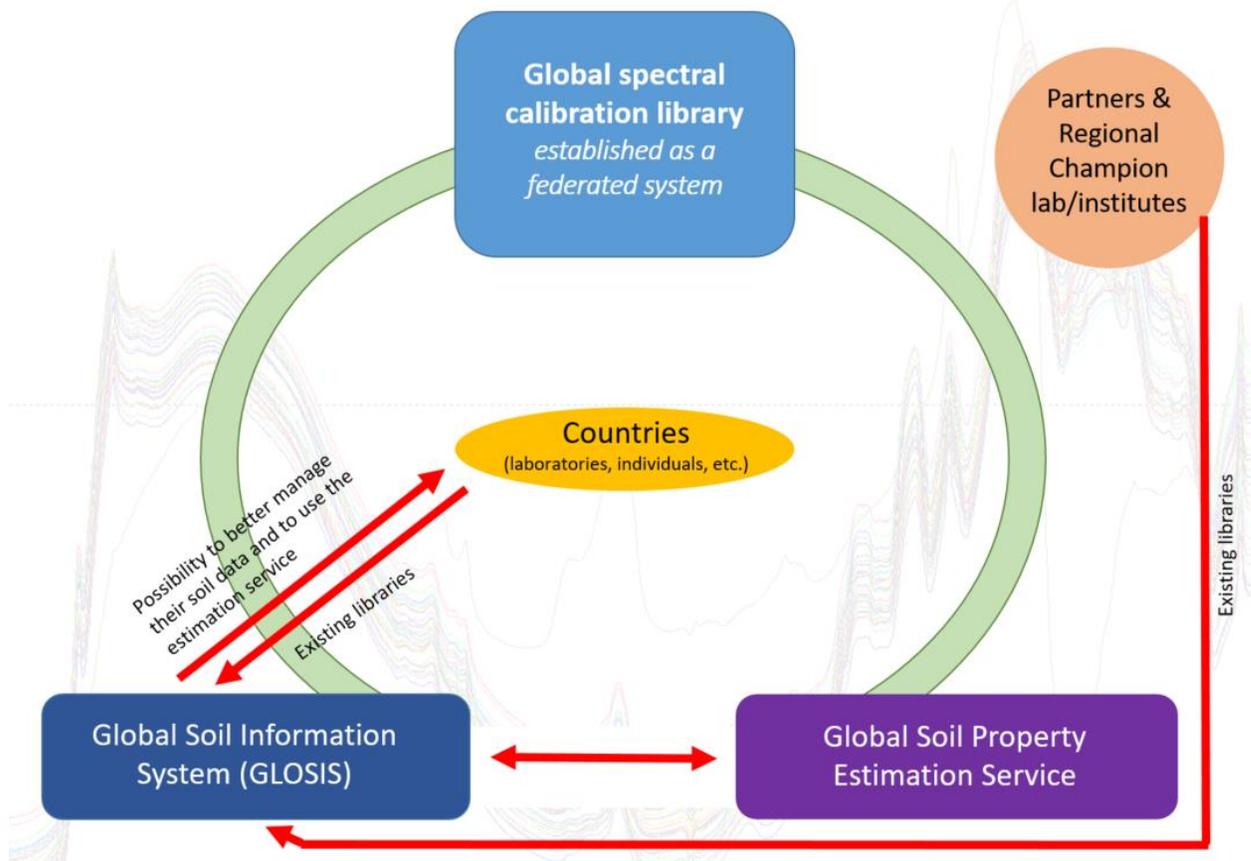


Figure 9. Interactions with the Global Soil Information System.

The global soil information system (GLOSIS) will be connected to the global soil spectral calibration library and to the global soil property estimation service. Soil spectroscopy partners, regional champion laboratories, and countries can contribute to GLOSIS through their existing libraries. GLOSIS will allow countries to better manage their soil data and use the estimation service.

Points of attention:

- How else can partners and countries contribute to GLOSIS? It was suggested that partners and countries can become GLOSIS nodes and become part of the Global Soil Information System (GLOSIS). The following steps are to be discussed by the INSII (International Network of Soil Information Institutions) and the Pillar 4 Working Group and will be communicated to the partners. It is now suggested that laboratories connect to their national nodes, which connect to GLOSIS.
- How to establish the connection between the library, GLOSIS, and the estimation service? The working groups on the library and the estimation service will have to address this issue. The pillar 4 working group is currently working on soil data exchange tools and procedures. It will work on possible solutions to connect existing and new spectral libraries and estimation services to the GLOSIS and GLOSIS nodes. A joint working group will be established for further discussions.

- Is it satisfactory to work with other existing libraries only in GLOSIS? The plenary decided that it is satisfactory to work with other existing libraries only through GLOSIS. However, those with existing libraries can send reference samples to the KSSL and other regional champion laboratories.

3.2. Regional champion laboratories on soil spectroscopy

After agreeing on the need to identify regional champion laboratories or institutes for soil spectroscopy, the participants revised and endorsed the Terms of Reference for the position (see Annex III). Ms. Caon informed the participants of the laboratories that volunteered or were called upon to take this position in each region:

- In Sub-Saharan Africa:
 - World Agroforestry (ICRAF) and Innovative Solutions for Decision Agriculture (iSDA), Kenya
 - International Institute of Tropical Agriculture (IITA), Nigeria
- In the Middle East and North Africa:
 - Center for Soil and Fertilizer Research in Africa, Mohammed VI Polytechnic University, Morocco
 - Institut de Recherche au Service du Développement Agricole (INRA), Morocco
- In Asia:
 - Rural Development Administration, Republic of Korea
 - Institute of Soil Science, Chinese Academy of Sciences, China
 - Indian Institute of Soil Science, Bhopal, India
- In the Pacific³:
 - University of Sydney, Australia
 - Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
 - Curtin University, Australia
- In Europe and Eurasia:
 - Rudn University, Russian Federation
 - Eco-analytical Laboratory, Department of Soil Science, Institute of Biology of Komi Scientific Center of the Ural Branch, Russian Federation
 - Walloon Center, Belgium
 - Joint Research Center of the European Commission
 - Ghent University, Belgium

³ Please note that laboratories and soil spectroscopy institutes in the Pacific are currently discussing a strategy for coordinating efforts. Mr. Rob de Hayr (GLOSOLAN vice-Chair from Australia) is coordinating the work and discussions.

- University of Twente, Netherlands
 - AgroCares, Netherlands
 - Aarhus University, Denmark
 - Rothamsted Research, United Kingdom
 - Hohenheim University, Germany
 - The Remote Sensing Laboratory at Tel Aviv university (RSL-TAU) , Israel
- In North America:
- United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil and Plant Science Division (SPSD), National Soil Survey Center (NSSC)
- In Latin America:
- University of Sao Paulo, Brazil

Participants had the opportunity to make a preliminary decision on which laboratory or institute they would like to have as regional champion. However, they requested additional information in order to make a final decision. It was decided that the GLOSOLAN coordinator will contact each of the potential regional champion laboratories or institutes listed above and will ask them to:

- Confirm their availability to take on this role
- Provide the name of a contact person in GLOSOLAN
- Provide a brief description of their laboratory or institute with a note on why they would be a perfect candidate for the position of regional champion
- Complete a form (based on the Terms of Reference in Annex III) in which they clearly indicate what they could offer to other laboratories in their region and help them with. Information should be provided on the costs that candidates could bear themselves and the costs for which they would require GLOSOLAN's support.

This information will be sent to the GLOSOLAN members in each region who will make the final decision. Once the regional champion laboratories have been identified, their profile will be published on the GLOSOLAN webpage.

4. GLOSOLAN documents on soil spectroscopy

Mr. Keith Shepherd presented the proposal of GLOSOLAN for the drafting of the guidelines for spectral measurement (see table of content of the good practice guidelines in Annex IV). The standard operating procedures (SOPs) for the use of the global soil spectral calibration library and the global soil property estimation service include:

- For recording the spectra: (i) sample preparation, (ii) sample loading, (iii) spectral method (settings), (iv) instrument maintenance, and (v) quality monitoring.
- For using the service: (i) sample submission guidelines, (ii) submitting spectra, (iii) outlier detection, and (iv) accessing the library.

SOPs on sample preparation and spectral measurement should be prepared for (i) the master instrument and its variations, (ii) similar instruments (require the development of calibration transfer algorithms), and

(iii) different but more commonly used instruments (require the development of calibration transfer algorithms). It was decided to prioritise the production of SOPs and calibration transfer algorithms and not to proceed for the time being with the development of the more general guidelines outlined in Annex IV.

Because of the interest of GLOSOLAN to collaborate with the IEEE Standard Association (IEEE SA), Mr. Eyal Ben Dor from the University of Tel Aviv introduced to the participants the standard protocol scheme for measuring soil spectroscopy under the IEEE SA umbrella. It should be noted that the IEEE SA publishes more than 100 standards per year thanks to the work of several thematic working groups. IEEE standards are available to the IEEE members for free. GLOSOLAN members could contribute to the work of the IEEE working group on “standard development process IEEE P4005” on one of the following themes:

1. optical operational scheme (0.4-2.5 μm)
2. thermal operation scheme (3-15 μm)
3. data saving and archiving (optical and thermal)
4. cross calibration for spectral exchange (optical and thermal)
5. spectral performance assessment for optical and thermal spectral ranges
6. field operational scheme

However, the terms of cooperation between GLOSOLAN and the IEEE SA need to be better discussed as copyright issues could arise.

4.1. Decision making on the writing of soil spectroscopy documents in GLOSOLAN

Ms. Caon introduced the participants to the procedure used by GLOSOLAN to harmonize its standard operating procedures for wet chemistry analysis. Once GLOSOLAN has agreed on the SOPs to be harmonized, the regional leaders are identified. The regional leaders are experts in specific methods and are tasked to:

- Prepare the matrix for the collection of information on the procedure used by each laboratory;
- Harmonize the information received first at the regional level and then at the global level;
- Draft the SOPs according to the GLOSOLAN SOP report template;
- Implement the changes suggested during the review phase;
- Finalize the SOP.

Per each SOP, a global leader is also identified. This expert takes overall responsibility for the harmonization of the SOP.

Thereafter, Ms. Caon asked the plenary to express their views on the type of documents to be produced under the initiative and the type of approach to be used for their drafting; that is, the approach used to write the GLOSOLAN documents on wet chemistry compared to the documents written by the working groups. She also reminded the participants that all documents should be written in a simple format and using only the English language. In this regard, the content of documents should be immediately understandable. The text should be understandable to people whose mother tongue is not English and who may be called upon to translate into other languages.

The plenary agreed to write SOPs on soil spectroscopy using the approach on wet chemistry explained above. The drafting of manuals, training materials, flyers, and communication materials was assigned to the working groups. In addition, the plenary agreed to collaborate with the IEEE SA. The GLOSOLAN

coordinator and the working group leaders on soil spectroscopy will act as GLOSOLAN contact persons at the IEEE.

The list of publications on soil spectroscopy on which GLOSOLAN will work in 2020-2021 is reported in table 3.

Table 3. List of publications on soil spectroscopy on which GLOSOLAN will work in 2020-2021.

Type of document	Topic	Leading author (IEEE or GLOSOLAN) <i>This is the one that initiated and is leading the work</i>	IEEE or GLOSOLAN contribution	Deadline
Multiple SOPs (1 per each instrument type)	Samples preparation and spectral measurement: <ul style="list-style-type: none">- Master instrument and variations on that- similar instruments (require transfer)- different but most commonly used instruments (require transfer)	GLOSOLAN	To be defined	Endorsement of the document in September 2021
SOP	Procedures for data treatment	GLOSOLAN	To be defined	TBC by the WG on estimation service
Training material (videos)	How to perform the SOPs	GLOSOLAN	To be defined	November 2021
Standard	Optical Operational Scheme	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG 2022
Standard	Thermal Operational Scheme	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG

				2022
Standard	Data saving and archiving (optical + thermal)	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG 2022
Standard	Cross calibration for spectral exchange (optical + thermal)	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG 2022
Standard	Spectral performance assessment for optical and thermal spectral ranges	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG 2022
Standard	Field operational scheme (optical)	IEEE	Writing, review, and finalization of the document, depending on the GLOSOLAN members that feel like contributing to the work	8 October: GLOSOLAN members interested to this work to join the IEEE meeting P4005 WG 2022

5. Financial resource mobilization

The GLOSOLAN initiative on soil spectroscopy is new to the Global Soil Partnership, FAO. In this regard, GLOSOLAN is to apply for projects to financially support the implementation of activities on soil spectroscopy.

All partners and GLOSOLAN members are welcome and kindly invited to apply for:

- Independent projects: All those who wish to apply for funding on an individual basis should inform the GLOSOLAN coordinator in order to avoid overlap and duplication. Thereafter, the GLOSOLAN coordinator, the GLOSOLAN Chair and vice-Chair, and the working group leaders will moderate the discussion with the working group and identify priorities to be included in the project proposals.
- Joint projects: All funding opportunities that partners and GLOSOLAN members wish to explore with the GSP/FAO should be coordinated by the GLOSOLAN coordinator.

6. Contribution of independent projects to the GLOSOLAN work plan on soil spectroscopy

All GLOSOLAN members and partners on soil spectroscopy who currently have a project that can contribute to the implementation of the GLOSOLAN work plan on soil spectroscopy should contact the GLOSOLAN coordinator at lucrezia.caon@fao.org. To facilitate the exchange of information, the GLOSOLAN coordinator will send an email to all GLOSOLAN members and partners on soil spectroscopy asking for the following information:

- Project title
- Project duration
- Project manager (name, last name, institution, country, email address)
- How the project could contribute to the GLOSOLAN initiative on soil spectroscopy
- Approval of the publication of jointly produced documents on the GLOSOLAN website for free
- Approval of the online availability of jointly produced tools for free

Ultimately, it is possible for GLOSOLAN to collaborate with ongoing projects if the documents and tools are made available online in open access.

7. GLOSOLAN work plan on soil spectroscopy for the years 2020-2021

The GLOSOLAN work plan for 2020 is reported in Table 4.

Table 4. GLOSOLAN work plan for the years 2020-2021

Activity	Responsible party	Deadline
General assignments		
Contact the ITPS Chair to ask for clearance on their role	GLOSOLAN Coordinator	25 September 2020
Collect inputs on the possibility to have an amendment to the GSP Soil Data Policy	GLOSOLAN Coordinator	15 October 2020
Contact all the regional champion laboratories/institutes identified during the meeting: <ul style="list-style-type: none"> - confirmation on their availability to take up this role - get the name of a contact person - ask them to complete a form (based on the ToR) to let laboratories and regions know about what they can offer and help with - publication of this information on the GLOSOLAN website 	GLOSOLAN Coordinator	December 2020 It depends on how fast regional champion laboratories / institutes are in getting back to the GLOSOLAN Coordinator
Inform GLOSOLAN members on the outcomes of the first plenary meeting on spectroscopy and move forward establishing the working groups: <ul style="list-style-type: none"> - general WG on spectroscopy - WG on the development of the spectral calibration library - WG on the development of the global soil property estimation service 	GLOSOLAN Coordinator	30 October 2020

<p>The email should inform GLOSOLAN members on INSII in case they would like to help with developing GLOSIS and connecting it to the global spectral calibration library and the global soil property estimation service.</p>		
<p>Global Spectral Calibration Library</p>		
<p>Report the suggestions of GLOSOLAN on the data review period to the USDA and report back to GLOSOLAN members</p>	<p>GLOSOLAN Coordinator</p>	<p>30 October 2020 depending on how much time it would take to the USDA to make a decision</p>
<p>Ask all GLOSOLAN members and participants at the first plenary meeting on spectroscopy if:</p> <ul style="list-style-type: none"> - they would like to send samples to the USDA - they would like to send samples to their regional champion laboratories and work with them - they will analyse the samples themselves and work with their regional champion laboratories / institutes - what type of spectra they analyse and with what instruments - if they have a spectral library already (please provide details) <p>All information will be organized in a database to be used by the WGs. Follow up actions will be taken with those willing to work with the USDA and other regional champion laboratories / institutes.</p>	<p>GLOSOLAN Coordinator</p>	<p>December 2020</p>
<p>Ask regional champion laboratories / institutes to provide the following information:</p>	<p>GLOSOLAN Coordinator</p>	<p>December 2020</p> <p>This depends on the time needed to make the connection with the regional champion laboratories / institutes</p>

<ul style="list-style-type: none"> - wet chemistry and spectroscopy methods used - instruments used - soil sample preparation protocols in use 		
Process the information provided by the regional champion laboratories / institutes and plan the next steps on harmonization	WG on the library	February 2021
<p>Organization of the second meeting of the working group on the library aiming to:</p> <ul style="list-style-type: none"> - review work - work on the information provided by the regional champion laboratories / institutes 	GLOSOLAN Coordinator, WG leaders and WG on the library	End of January 2021
Organization of a first inter-laboratory comparison among regional champion laboratories	GLOSOLAN Coordinator, WG leaders, regional champion laboratories / institutes	<p>May – September 2021</p> <p>Together with the GLOSOLAN PT for wet chemistry</p>
<p>Identification of the soils missing in the KSSL library and compilation of a list of what regional champion laboratories / institutes can provide data for what soil type</p> <ul style="list-style-type: none"> - Identify gaps (need to work on the criteria for the identification of gaps) - regional champion laboratories/ institutes help filling in the gaps 	KSSL and regional champion laboratories / institutes, WG on the library	<p>February 2021</p> <p>In 2022 (after the inter-laboratory comparison is done and quality of data is checked)</p>
<p>Regional champion laboratories / institutes contact laboratories in their region:</p> <ul style="list-style-type: none"> - identification of laboratories that are using spectroscopy instruments - identification of laboratories that have 	Regional champion laboratories / institutes and local laboratories	<p>April 2021</p> <p>Need to finalize the guidelines for shipping samples to the KSSL</p> <p>The exchange of soil samples to other regional champions can start after the variability between regional champion</p>

<p>spectral calibration libraries</p> <ul style="list-style-type: none"> - assessment of needs in terms of capacity building - shipment of soil samples to KSSL first, to all other regional champion laboratories / institutes once quality is checked through the PT 		<p>laboratories / institutes is assessed.</p> <p>Regional champion laboratories specific guidelines for the shipment of soil samples might be prepared as well.</p>
Compilation of the software pieces to develop	Ms. Fenny van Egmond, ISRIC	30 October/November 2020
<p>Organization of the first meeting of the working group on the global spectral calibration library aiming to:</p> <ul style="list-style-type: none"> - review the software pieces to develop - agree on a work plan (including a timeline) - assign tasks - reflect on how the library, estimation service, and GLOSIS can be connected 	GLOSOLAN Coordinator, WG Leaders, WG on the library	30 November 2020
Calibration transfer research	WG on the library, IEEE	<p>September 2021</p> <p>Reporting on progresses every 6 months</p>
Global Soil Property Estimation Service		
<p>Organization of the first meeting of the working group on the global soil property estimation service aiming to:</p> <ul style="list-style-type: none"> - discuss the algorithms and models to develop/use - agree on a work plan (including a timeline) - assign tasks - reflect on how the library, estimation service, and GLOSIS can be connected 	GLOSOLAN Coordinator, WG Leaders, WG on the estimation service	15 December 2020
Writing of protocols and guidelines		

Start writing the document as per the work plan in Table 3.	GLOSOLAN Coordinator, WG, GLOSOLAN members	September 2021
Finalize the discussion on the collaboration between GLOSOLAN and the IEEE SA	GLOSOLAN Coordinator and Eyal Ben Dor	October 2020
Ask GLOSOLAN members if they would like to join any IEEE working group	GLOSOLAN Coordinator	October 2020
Training and webinars		
Organization of a series of webinars on the installation, use, and maintenance of spectroscopy equipment Combined with the use of protocols	GLOSOLAN Coordinator, WGs, manufacturers, regional champion laboratories / institutes	September 2021
Webinar on the standard operating procedures produced in 2020-2021	GLOSOLAN Coordinator, WGs	September 2021
Organization of training courses on the use of different software packages for soil spectral data	Working group on spectroscopy	September 2021
Projects		
Writing of project proposals for covering the following costs: <ul style="list-style-type: none"> - shipment and analysis of soil samples to the USA and the regional champion laboratories - organization of a inter-laboratory comparison among regional champion laboratories/institutes - training and remote support (if needed) - development of the global spectral calibration library and the global soil property estimation service 	GLOSOLAN Coordinator, WG leaders and WGs (general, library and estimation service)	December 2020
Identification of projects (outside GLOSOLAN) that can contribute and are willing to contribute to the implementation of the	GLOSOLAN Coordinator, WG leaders, WGs, partners, GLOSOLAN members	September 2021 [continuous activity]

GLOSOLAN work plan on spectroscopy.		
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8. Venue and time of the next meeting

The second plenary meeting on soil spectroscopy will take place in September 2021 either virtually or in person depending on the evolution of the COVID-19 pandemic.

Annex I: Agenda



Food and Agriculture
Organization of the
United Nations



First Plenary Meeting on Spectroscopy

23-25 September 2020

From 11 AM to 1 PM CET

Online meeting – Zoom platform

Wednesday, 23 September 2020		
11:00 - 11:10AM CET	Opening	Mr. Ronald Vargas, FAO Ms. Nopmanee Suvannang, GLOSOLAN Chair
11:10 – 11:15 AM CET	Endorsement of the Agenda and group picture	Ms. Lucrezia Caon, GLOSOLAN coordinator, FAO
11:15 – 11:35 AM CET	Item 1: Introduction to spectroscopy	Mr. Keith Shepherd, ICRAF/iSDA
11:35 – 11:55 AM CET	Item 2: Presentation of the results of the global survey on spectroscopy needs	Ms. Fenny van Egmond, ISRIC
11:55AM – 12:25PM CET	Item 3: Presentation of the GLOSOLAN concept notes on spectroscopy: <ul style="list-style-type: none"> - The global soil spectral calibration library and estimation service - Capacity development in soil spectroscopy 	Mr. Christian Omuto, FAO
12:25 – 1:00PM CET	Item 4: Organization of work <ul style="list-style-type: none"> - Working group on spectroscopy - Assignment of work and tasks - Decision making process 	Moderator: Ms. Lucrezia Caon, FAO

Thursday, 24 September 2020		
Global spectral calibration library and estimation service		
11:00 -11:20AM CET	Item 5: Introduction to the global soil calibration library	Mr. Richard Ferguson, USDA
11:20AM – 12:40PM CET	Item 6: Discussion <ul style="list-style-type: none"> - Sample submission guidelines - Data use and management - Data governance: copyright and publishing issues - Calibration models and approach (touch down on instruments) - Distribution of work 	Moderator: Mr. Ronald Vargas, FAO
12:40 – 1:00PM CET	Item 7: Regional champion labs/institutes on spectroscopy <ul style="list-style-type: none"> - Needed/useful or not? - Terms of reference - Identification 	Moderator: Ms. Lucrezia Caon, FAO

Friday, 25 September 2020

Guidelines for spectral measurements

11:00 – 11:15AM CET	Item 8: Presentation of the proposal for writing the guidelines for spectral measurements	Mr. Keith Shepherd, ICRAF/iSDA
11:15 – 11:30AM CET	Item 9: The IEEE and the P4005 Standard Protocol and Scheme for Measuring Soil Spectroscopy	Mr. Eyal Ben Dor, Tel Aviv University
11:30AM – 12:20PM CET	Item 10: Discussion <ul style="list-style-type: none"> - Content of the guidelines for spectral measurement - Approach to the writing of the guidelines: will we use the same approach used by GLOSOLAN in wet chemistry? - How can the collaboration with IEEE work? Division of tasks & copyright issues 	Moderator: Ms. Lucrezia Caon, FAO
Project proposal writing and cooperation with individual projects		
12:20 - 12:40PM CET	Item 11: Financial resource mobilization strategy	Ms. Lucrezia Caon, FAO
12:40 – 1:00PM CET	Item 12: Discussion <ul style="list-style-type: none"> - How can individual projects contribute to implementing the GLOSOLAN work plan? - Copyright issues: tools, data and documents produced by or in collaboration with individual projects 	Moderator: Ms. Lucrezia Caon, FAO
1:00PM CET	Review of the work plan 2020-2021 and closure of the meeting	

Annex II. List of participants

	Name and last name of the participant	Laboratory/institution
Afghanistan	Abdul Waris (Nizam)	Nangrahar Research Laboratory, Agricultural Research Institution of Afghanistan (ARIA)
Afghanistan	Ahmad Wali Wali	KSL, Kandahar Research Farm
Afghanistan	Sayed Azmar Sadat	Nangarhar research Laboratory, Agriculture Research Institute of Afghanistan (ARIA)
Afghanistan	Sayed Mateen Rasooli	Nangarhar research Laboratory
Argentina	Nanci Kloster	EEA Anguil – RILSAV. Instituto Nacional de Tecnología Agropecuaria
Australia	Alex Mcbratney	Sydney Institute of Agriculture, University of Sydney
Australia	Raphael VISCARRA ROSSEL	Curtin University
Austria	Francesco Vuolo	Institute of Geomatics, Universität für Bodenkultur Wien
Austria	Maximilian Lippel	AGES - Austrian Agency for Health & Food Safety
Belgium	Abdul Mouazen	Precision SCoRing laboratory, Ghent University
Belgium	Bas Van Wesemael	Earth and Life Institute, UCLouvain
Belgium	Clémence MARIAGE	Axe Echanges Eau-Sol-Plante, GxABT – Liège University
Belgium	Gilles Colinet	Axe Echanges Eau-Sol-Plante, GxABT – Liège University
Belgium	Kristof Tirez	VITO
Belgium	Muhammad Abdul Munnaf	Precision SCoRing laboratory, Ghent University
Belgium	Seyed Hamed Javadi	Precision SCoRing laboratory, Ghent University
Brazil	Jose Alexandre Melo Dematte	University of Sao Paulo
Brazil	Ricardo Dalmolin	Federal University of Santa Maria
Cambodia	Boreborey Ty	Soil laboratory, Institute of Technology of Cambodia (ITC)
Cambodia	Pinnara Ket	Soil laboratory, Institute of Technology of Cambodia (ITC)
Cambodia	Vannak Ann	Soil laboratory, Institute of Technology of Cambodia (ITC)
Cameroon	Amina Aboubakar	LASPEE / IRAD
Cameroon	Mfopou Mewouo Yvette Clarisse	LASPEE / IRAD
Cameroon	Nzeket Aline Beatrice	LASPEE / IRAD
Cameroon	Rose Ndango	Analytical Services Laboratory, International Institute of tropical Agriculture (IITA)
Cameroon	Zing Zing Bertrand	LASPEE / IRAD
Colombia	Angélica María Sánchez	National Soil Laboratory, Agustín Codazzi Geographic Institute
Colombia	Armando Daniel Ochoa Castro	National Soil Laboratory, Agustín Codazzi Geographic Institute
Colombia	Laura Uribe Triana	Laboratorio Tecnianálisis S.A.S.
Colombia	Mary Ardila Quintana	National Soil Laboratory, Agustín Codazzi Geographic Institute
Colombia	Nancy Leiva Gutiérrez	National Soil Laboratory, Agustín Codazzi Geographic Institute
Colombia	Rosalina Gonzalez	La Salle University Soil Laboratory
Croatia	Ivana Šestak	Department of General Agronomy, Agroecology Section, Laboratory for analytical chemistry, University of Zagreb Faculty of Agriculture
Denmark	Maria Knadel	AGRO University laboratory, Aarhus University

Ethiopia	Musefa Abegaz	Soil Laboratory of Holeta Agricultural Research Center, Ethiopian Institute of Agricultural Research Center (EIAR)
European Commission	Luca Montanarella	JRC
European Commission	Mirco Barbero	European Commission
European Commission	Arwyn Jones	Joint Research Centre
FAO/IAEA	Christian RESCH	Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, International Atomic Energy Agency
FAO/IAEA	Franck ALBINET	Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (Consultant), International Atomic Energy Agency
FAO/IAEA	Gerd DERCON	Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, International Atomic Energy Agency
FAO/IAEA	Tetsuya EGUCHI	Soil and Water Management & Crop Nutrition Laboratory, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (Consultant), International Atomic Energy Agency
Fiji	Deeksha Krishna	Soil science Lab, Fiji National University
FIJI	Dorren Pillay	Analytical Lab, Sugar Research Institute Of Fiji
France	Gomez Cecile	LISAH / IRD
Georgia	Giorgi Ghambashidze	Laboratory of Soil Fertility Research Service, Scientific-Research Centre of Agriculture
Germany	Elke Fries	Federal Institute for Geosciences and Natural Resources (BGR), Sub-Department "Soil as a Resource – Properties and Dynamics"
Germany	Laura Schnee	University of Bremen
Germany	Michaela Frei	Federal Institute for Geosciences and Natural Resources (BGR), Sub-Department "Soil as a Resource – Properties and Dynamics"
Ghana	Prosper & Amenuvor	CSIR-Environmental Analytical Laboratory, CSIR-Savanna Agricultural Research Institute
Ghana	Sebastian Brahene	FAO RAF
Greece	Konstantinos Karyotis	Interbalkan Environment Center
Hungary	Mohammed Zein	Soil science laboratory, Szent Istvan University, Gödöll, Hungary
India	Ashok K Patra	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
India	Chenna Vijaya Ranganatha	CRAL, ICRISAT
India	Chetna Nimje	CRAL, ICRISAT
India	Dhiraj Kumar	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
India	Jyoti K Thakur	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
India	Kuntal Mouli Hati	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
India	M. Vassanda Coumar	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India

India	Monoranjan Mohanty	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
India	Nishant K Sinha	Soil Spectroscopy /Soil Physics Laboratory. ICAR-Indian Institute of Soil Science, Bhopal, India
India	Pradip Dey	Soil Spectroscopy /Soil Physics Laboratory. ICAR-Indian Institute of Soil Science, Bhopal, India
India	Pramod Jha	Soil Spectroscopy /Soil Physics Laboratory. ICAR-Indian Institute of Soil Science, Bhopal, India
India	Pushpajeet Choudhari	CRAL, ICRISAT
India	Ranjeet Singh Chaudhary	Soil Spectroscopy /Soil Physics Laboratory, ICAR-Indian Institute of Soil Science, Bhopal, India
Indonesia	Arifin Fahmi	Laboratory of BALITTRA (ISARI)
Indonesia	Eni Maftuah	Laboratory of BALITTRA (ISARI)
Iraq	Bassam Abdul Jabbar	Soil Laboratories, Office of Agricultural Researches Ministry of Agriculture
Iraq	Saifuldeen A. Salim	Soil and Water, Center of Desert Studies, University of Anbar
Iraq	Saifuldeen A. Salim	Soil and Water Lab., Center of Desert Studies, University of Anbar
Iraq	Shamil Esmael	Soil and Water Lab., Center of Desert Studies, University of Anbar
IRAQ	Sadeq J. H. Dwenee	Soil chemistry Lab. / Soil and water resources center, Directorate of agricultural research, Ministry of science and technology
Israel	Eyal Ben Dor	Tel Aviv University
Japan	Hideo Kubotera	Soil Inventory Unit, Institute for Agro-Environmental Sciences, National Agriculture and Food Research Organization (NARO)
Jordan	Elham Abu Ruman	Fertilizer /NARC
Jordan	Isra Kharabsheh	Water, NARC
Jordan	Nabeel Bani Hani	Soil/NARC
Kenya	Bernard Waruru (Dr.)	National Agricultural Research Laboratories -KALRO
Kenya	Elvis Weullow	Soil Plant Spectral Diagnostics Lab -World Agroforestry (ICRAF)
Kenya	Erick Towett	Soil Plant Spectral Diagnostics Lab -World Agroforestry (ICRAF)
Kenya	Esther Gikonyo (Dr.)	National Agricultural Research Laboratories -KALRO
Kenya	Hannah Karuri	University of Embu Soil Laboratory
Kenya	Keith Shepard	ICRAF, Kenya
Kenya	Leigh Winowiecki	Soil-Plant Spectral Diagnostics Lab World Agroforestry (ICRAF)
Kenya	Njeru Gachini (Mr.)	National Agricultural Research Laboratories -KALRO
Latvia	Aldis Butlers	Laboratory of Forest Environment, Latvian State Forest Research Institute "Silava"
Latvia	Lauris Leitāns	Agrochemical Laboratory, State Plant Protection Service
Lesotho	Malefetsane Khesuoe	Soils Lab, Department of Agricultural Research
Lesotho	Selebalo Ramakhanna	Soils Lab, Department of Agricultural Research
Madagascar	Andriamananjara Andry	Laboratoire des Radiosotopes
Madagascar	Rabenarivo Michel	Laboratoire des Radiosotopes
Madagascar	Razafimanantsoa Marie Paule	Laboratoire des Radiosotopes
Madagascar	Razafimbelo Tantely	Laboratoire des Radiosotopes
Mali	Djénéba DEMBELE BA	Chercheuse en Science des sols/SIG/Téledétection, Institut d'Economie Rural (IER), Sotuba, Mali

Mali	Drissa Traoré	Soi-Water-Plant laboratory, Institute of Rural Economy
Mexico	Mario Guevara	University of Delaware
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Terms of Reference

GLOSOLAN's Technical Working Group on Soil Spectroscopy

Background

Spectroscopy is the study of the interaction between matter and electromagnetic radiation. It is based on the principle that molecular vibrations and electronic transitions associated with soil constituents absorb light while interacting with radiation. Soil spectroscopy is a method that has the potential of more rapidly and cost-effectively measuring soil properties in the lab and in the field. Soil spectral analysis estimates soil properties by calibrating conventional reference measurements, like wet chemistry soil tests, to the spectral signatures. The potential of spectral technology in soil mapping and monitoring is tremendous as it is fast, cost-effective, environmentally friendly, nondestructive, reproducible and repeatable. Numerous soil properties can be directly calibrated to near- and mid-infrared spectra (MIR) due to the fact that spectral signatures respond to soil mineral and organic composition.

In April 2020, GLOSOLAN officially launched its initiative on soil spectroscopy that was consolidated through the organization of the first plenary meeting on soil spectroscopy on 23-25 September 2020. For the first time since the discovery of this technology, institutions and experts from around the world are now joining efforts to use this technology to support decision making on soil protection globally.

Composition and governance

The technical working group will act under the umbrella of the Global Soil Laboratory Network (GLOSOLAN) and under the direction of the GLOSOLAN Chair and vice-Chair. The GLOSOLAN Coordinator will provide support as a facilitator.

The technical working group is led by one or more leader(s) working in coordination with the GLOSOLAN Chair, GLOSOLAN vice-Chair, and GLOSOLAN Coordinator at the Global Soil Partnership. The term for the leader(s) is two years after election. The appointment of the working group leader(s) and the extension of their mandate to a second term will take place during the annual plenary meeting on spectroscopy.

The working group leader(s) are responsible for:

- i. Supporting and ensuring the timely implementation of the GLOSOLAN work plan on spectroscopy;
- ii. Reporting on spectroscopy activities at the annual GLOSOLAN meeting;

- iii. Representing the working group on spectroscopy at any other GSP meetings or international events;
- iv. Supporting the GLOSOLAN Coordinator in capacity-building and financial-resources-mobilization activities;
- v. Ensuring that the activities of the working group are implemented according to the principles of GLOSOLAN, including transparency, inclusivity, and respect; and
- vi. Coordinating cooperation with projects and initiatives that contribute to the aims of the working group, including research, service, and capacity development.

All members of the working group are to be experts on the topic of soil spectroscopy. Representatives from the Regional Champion Laboratories/Institutes on soil spectroscopy must also be part of the working group.

At least one member of the Intergovernmental Technical Panel on Soils (ITPS) should be part of the working group on soil spectroscopy. In this regard, the identified expert(s) should assist the GLOSOLAN Coordinator in reporting on GLOSOLAN activities to the ITPS. Because GLOSOLAN works on harmonization and GLOSOLAN documents are released after long discussions among laboratories, countries, and implementing partners, documents produced under GLOSOLAN do not require the approval of the ITPS before publication. The opinion and clearance of the ITPS and that of the GSP Plenary Assembly are required only for documents that have political implications, such as the “Resolution for the International Exchange of Soil Samples for Research Purposes under GLOSOLAN” (presented and approved at the Seventh GSP Plenary Assembly in 2019), and for the launch of new initiatives, such as the initiative on soil spectroscopy (presented and approved at the Seventh GSP Plenary Assembly in 2019) and the initiative on soil fertilizer analysis (presented and approved at the Eighth GSP Plenary Assembly in 2020).

The group will be organized in sub-groups based on the GLOSOLAN work plan for soil spectroscopy. In accordance to the decision-making process endorsed for this initiative by GLOSOLAN members and partners on soil spectroscopy, the working group should work in close contact with countries and laboratories (see the report of the First Plenary Meeting on Soil Spectroscopy). Countries and laboratories will provide the working group with data and information to develop standards, tools, and other soil spectroscopy materials and will review draft documents and prototype tools developed by the working group.

The number of members in the working group is not limited. The GLOSOLAN Coordinator and the working group leader(s) should ensure to the best of their ability that the working group has an appropriate geographical balance and representation of members. All GLOSOLAN members receive regular updates on the work of the network on spectroscopy; it is not necessary to register in the working group to be informed of its activities.

New members of the technical working group

Experts interested in joining the working group can send an expression of interest to the GLOSOLAN Coordinator any time. Each will join the working group after providing a short summary of their experience and interest in the GLOSOLAN work on soil spectroscopy. The summary is intended to ensure that member’s skills are used to best effect and that member’s interests in contributing to GLOSOLAN are met. The GLOSOLAN Coordinator and the working group leader(s) will consider the applicant’s:

- Reputation as an expert on spectroscopy;
- CV and publication list;
- Participation in projects that could help to implement the GLOSOLAN work plan on soil spectroscopy; and
- Time available to commit to GLOSOLAN.

The technical working group on spectroscopy will:

- i. Contribute to the preparation (writing, revision, and finalization) of spectroscopy materials, such as protocols, guidelines, manuals, and training material and videos;
- ii. Advise laboratories working on or interested in working on spectroscopy as needed and support capacity building activities;
- iii. Coordinate the establishment of the global spectral calibration library and the development of tools for the calibration service;
- iv. Coordinate joint writing of publications;
- v. Support the organization of the annual plenary meetings on spectroscopy;
- vi. Contribute to the development of the annual GLOSOLAN work plan on spectroscopy;
- vii. Promote GLOSOLAN at the global, regional, and national level, motivating other laboratories to join the network; and
- viii. Contribute to the mobilization of financial resources under GLOSOLAN.

Work plan and functioning

Every year, the GLOSOLAN work plan on soil spectroscopy is discussed at the plenary meeting on soil spectroscopy, which is attended by all GLOSOLAN members and partners on soil spectroscopy. The work plan lists all the activities on soil spectroscopy to be implemented by GLOSOLAN for one year, assigns tasks to partners, and specifies deadlines. The activities in the work plan are based on the concept notes: [“A Global Soil Spectral Calibration Library and Estimation Service”](#) and [“Global Capacity Development in Soil Spectroscopy.”](#) The work plan is presented at the annual GLOSOLAN meeting for final endorsement.

To ensure the active and constructive participation of all experts, the GLOSOLAN Coordinator will monitor the activities of the working group and its members. Inactive members will be contacted by the GLOSOLAN coordinator and eventually removed from the working group. The working group is based on the willingness of its members to jointly achieve a common goal. In this regard, all members commit to a positive and constructive approach that facilitates the work.

Regional Champion Laboratories and/or Institutes

To promote the implementation of GLOSOLAN activities on soil spectroscopy at the national and regional level and to break language and cultural barriers, regional champion laboratories and/or institutes are identified and re-confirmed at the annual plenary meetings on spectroscopy. Ideally, at least one regional champion laboratory/institute should be identified per region: Sub-Saharan Africa, Middle East and North Africa, Europe, Eurasia, Asia, North America, South America and the Caribbean, and the Pacific. If this is not possible, a champion laboratory/institute can volunteer to serve more than one region. In such case, the following criteria should be considered:

- Regional proximity,
- Cultural and language similarities, and
- Expertise on different aspects of soil spectroscopy.

Each region is free to identify either one or two laboratories or institutes to serve as regional champions. Each region can identify sub-regional champions to better assist countries in the area. The sub-regional champions should coordinate actions and be calibrated against the primary regional champions.

By accepting to serve as regional champion laboratory and/or institute, a laboratory and/or institute agrees to:

- i. Provide all the information needed by GLOSOLAN to harmonize procedures and ensure the comparability of data. The required information includes, but is not limited to, methods, instruments, and soil sample preparation protocols and methods used for wet chemistry and soil spectroscopy analysis;
- ii. Participate in the inter-laboratory comparisons organized by GLOSOLAN and take all actions needed to ensure the comparability of results with other regional champion laboratories and institutes;
- iii. Welcome and facilitate the work of the Panel in charge of approving the quality for the soil spectral data produced at their facilities that will be added to the global spectral calibration library;
- iv. Fill soil data gaps in the Kellogg Soil Survey Laboratory library so that representability and quality go together;
- v. Analyze the samples they receive from laboratories in their region while helping these laboratories to build their own libraries using GLOSOLAN's quality standards;
- vi. Support laboratories that are already using spectroscopy technology to implement GLOSOLAN standards and improve their performance in soil analysis. Such support might include the exchange of information and experience, the provision of remote or in-person trouble shooting, and guidance on the operation of equipment;
- vii. Guide laboratories that would like to start a spectral library in identifying and purchasing the right equipment, in training their staff, and in developing a well-functioning laboratory;
- viii. Assist GLOSOLAN in coordinating and implementing capacity-building programs in the region; and
- ix. Support GLOSOLAN with downscaling activities on spectroscopy, such as the development and use of calibration models and the shipment and analysis of soil samples. This support might include the organization of regional meetings, webinars, and exchange programs.

There is no time limit or term to the position of regional champion laboratories and/or institutes. Regional champion laboratories and/or institutes keep their role as long as they comply with the Terms of Reference in this document. In case of need, a position will be revised at the first available plenary meeting on spectroscopy.

Annex IV. Table of content of the good practice guidelines

- 1. General introduction**
- 2. Introduction to spectroscopy**
 - a. Why use spectroscopy – role, added value
 - b. Basic principles of diffuse reflectance spectroscopy
 - c. Electromagnetic spectrum and wavelength ranges (visible, NIR, MIR)
 - d. Diffuse and direct reflectance
 - e. Absorbance vs reflectance
 - f. Dispersive vs fourier-transform
 - g. Low cost technology (diode, MEMS, chip)
 - h. Associated methods (ATR, transmission, far IR, photoacoustic)
- 3. Introduction to soil spectroscopy**
 - a. Soil adsorption features: mineral, organic, pollutants
 - b. Direct interpretation of soil spectra (VNIR, MIR)
 - c. Calibration of spectra to soil properties (brief)
 - d. Spectral processing
 - e. Spectral calibration methods
 - f. Wet chemistry reference data
 - g. Spectral indicators
 - h. Applications of soil spectroscopy
 - i. Advisory services
 - j. Soil carbon accounting
 - k. Digital soil mapping
- 4. Instruments in common use**
 - a. FT-MIR (KBr, ZnSe) benchtop
 - b. FT-NIR benchtop
 - c. Dispersive NIR benchtop
 - d. VNIR field/lab instruments
 - e. ATR
 - f. Handhelds
- 5. Optics options (light sources, mirrors, beamsplitters, detectors)**
 - a. Background and reference readings
 - b. Spectral range, bandwidth, spectral recording and sampling intervals
 - c. Performance metrics (signal-to-noise, etc.)
 - d. Sample presentation overview (fixed window, fibre-optic, contact, non-contact, through bags)
 - e. Operational and performance quality checks, diagnostics
 - f. Operating environment (temperature, humidity, CO₂)
 - g. Instrument maintenance
 - h. Instrument software
- 6. Soil sample preparation**
 - a. Field sampling (representativeness, depth location, cumulative mass, sub-sampling)

- b. Soil primary processing (drying, crushing, sieving, subsampling)
 - c. Labelling, QR/Bar codes
 - d. Potential errors along the sample processing chain
- 7. Soil sample presentation and reading**
- a. Use of KBr
 - b. Sample presentation options are specific to instrument and accessory
 - c. Microplates
 - d. Sample cups
 - e. Front-end & stand-off accessories
 - f. Optical window direct contact
 - g. Sample presentation options, consistency, field of view
 - h. Sample holders (glass, optical glass, polythene bags)
 - i. Number of scans, scanning time, replicate samples
 - j. Sample rotation
- 8. Spectral quality assurance and control**
- a. Use of standards
 - b. Visual check of spectra
 - c. Troubleshooting (moisture bands, CO₂ bands, saw-tooth, detector saturation, noise)
 - d. Automatic quality checks
- 9. Spectral calibration**
- a. Objectives
 - b. Reference data methods
 - c. Transformation of spectral and reference data
 - d. Common spectral pre-processing that works
 - e. Special features of spectral data (correlation, heteroscedasticity, overfitting)
 - f. Sample selection
 - g. Data preparation
 - h. Outlier detection, handling
 - i. Methods (PCA, PLSR, MBL, neural nets, ensemble)
 - j. Local vs global
 - k. Resampling
 - l. Hold-out validation
 - m. Performance metrics
 - n. Robustness
 - o. Estimation
 - p. Outlier detection and follow-up
 - q. Model versioning
 - r. Iterative spectral library building
 - s. Error metrics
 - t. Pattern matching
 - u. Clustering
 - v. Reference property classification
 - w. Spectral indicators independent of reference data
- 10. Laboratory information management systems and software tools**

- a. Recording metadata. Potential to link to GLOSIS
 - b. Spectral instrument metadata
 - c. Sample tracking and management
 - d. Physical soil archive management
 - e. Software systems – link spectral data to reference data
 - f. Available database and software tools
- 11. Spectral prediction performance**
- a. What predicts well, not so well, not at all
 - b. Summary of literature
- 12. Digital soil mapping application**
- a. National soil information systems
 - b. Covariates
 - c. Digital soil mapping methods
 - d. Error propagation
 - e. Spatial-spectral calibration
 - f. Examples
 - g. Soil monitoring using spectra
- 13. Soil testing and advisory services application**
- a. Fertilizer advisory
 - b. Pollution monitoring
 - c. Mobile labs
 - d. Rural labs
 - e. Handheld field scanners
- 14. Soil carbon accounting application**
- a. Soil monitoring
 - b. Repeated lab measurements
 - c. In-field scanning
 - d. Core scanning
 - e. Systems
 - f. Reporting
- 15. Future developments**
- a. Machine learning and artificial intelligence advances
 - b. Instrument advances
 - c. Distributed ledger systems, e.g. blockchain
 - d. Etc.