GLOSOLAN/18/Survey Report

Food and Agriculture Organization of the United Nations

GLOBAL SOIL PARTNERSHIP

Report

Evaluation of the First Global Soil Laboratory Network (GLOSOLAN) online survey for assessing soil laboratory capacities

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Rome, Italy, Friday, December 14, 2018

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Table of Contents

List of figures

List of tables

List of acronyms and abbreviations

Executive summary

The analysis of the answers to the first worldwide survey about laboratories undertaking soil analyses: (i) demonstrates the motivation of these laboratories to join an international network; (ii) confirms the need for the implementation of global harmonization and standardization of analytical procedures; (iii) shows the need for improving the knowledge and competence of laboratory staff; and (iv) suggests that addressing the existing quality assurance/quality control issues between laboratories should start at the regional level.

<u>Key findings</u>

- **The survey was viewed more than 700 times in 8 weeks, demonstrating the large worldwide interest about an initiative concerning soil laboratories. However, the survey or the platform used to launch the online survey were probably not well designed enough, as only 111 complete surveys could be assessed. Moreover, the low number of answers to some questions suggests a lack of clarity or an excess of complexity in the survey.**
- At the global scale, most of the responding laboratories were **not** yet **affiliated with a laboratory network**. Laboratories already involved in networks were generally affiliated with a national network and rarely with an international network. This suggests that international inter-comparability of data is currently infeasible.
- **Formal education** of laboratory staff is highly variable between regions. This demonstrates a need for targeted capacity building (especially in small-sized laboratories) through regional soil laboratory networks (RESOLANs).
- In some laboratories, a large percentage of temporary staff suggests that staff turnover may be high and the retention of experienced staff may be low. Moreover, the absence of regular **staff training** exacerbates the apparent lack of succession planning and mentoring.
- **In most cases, laboratory infrastructure**, facilities and equipment were appropriate and did not appear as a limiting factor for obtaining reproducible results.
- The methodologies and procedures for a set of basic soil analyses were highly variable between laboratories, even when located in the same Region. This suggests that at the moment, it is probably difficult to compare results at the global level, between different countries in a region, or even between different laboratories located in a single country;
- **Standard Operating Procedures** are generally written in the local language and seem to be well established, whereas maintenance and results logbooks are less utilized.
- **Quality control and quality assurance** are established in the majority of laboratories. However, in many laboratories, the frequency of the controls is too low to guarantee consistent quality of results.
- Laboratory **certification/accreditation** is not yet sufficiently established either regionally or internationally.

Recommended actions for GLOSOLAN

- To stimulate the development of standard operating procedures (SOPs), GLOSOLAN should propose draft SOPs for a suite of the most common or the most important soil parameters. At present, the operational procedures are so diverse, that it would be difficult to implement a single SOP for each parameter that would be adopted by soil laboratories world-wide. Consequently, it seems necessary to first identify which operational procedures are most likely to impact results obtained for each particular soil parameter. Then, based on this understanding, SOP could be designed to accommodate specific regional/local practices and parameter needs. This should be addressed during the GLOSOLAN second meeting.
- To improve staff qualifications, GLOSOLAN should develop e.books and videos to disseminate knowledge concerning good laboratory practices (GLPs) and provide information on specific aspects related to soil analysis. GLOSOLAN should also propose a training programme to increase staff competence that could be adopted on a regional scale and updated regularly.
- To facilitate the dissemination of such e.books and videos and the adoption of training programmes, it is suggested to stimulate the development of RESOLANs that do not yet exist.
- GLOSOLAN should motivate laboratories to implement internal quality control more frequently by using their internal control soils. By increasing the number of internal quality control analyses, laboratories can better assess, monitor and benchmark their precision and also detect systemic problems that need to be solved.
- GLOSOLAN should organise a proficiency testing program, or ring test, to benchmark the results of each method across laboratories. **Organized ring testscould be regularly administered at two levels: regional level and global level** to: 1) evaluate and monitor the performance of existing laboratories (accredited or not); 2) validate standard methods; and 3) set-up new laboratories and train staff.
- GLOSOLAN should establish one or two soil reference laboratories in each region to provide and deliver the necessary technical advice, training program and capacity building.
- GLOSOLAN should set up a communication platform to share information and experience among laboratories. This platform could host a database to gather, collect and review available literature (FAO/WEPAL/IPNI/IPPI/OECD).
- GLOSOLOAN should develop and promote a certified soil laboratory quality assurance system and provide a GLOSOLOAN accreditation scheme.

1 Introduction

The Global Soil Partnership (GSP) of the Food and Agriculture Organization of the United Nations (FAO) was established in 2012, with the purpose of promoting sustainable soil management (SSM) and strengthening soil governance at all levels. The GSP operates according to five Pillars of Action, within nine Regional Soil Partnerships.

The Global Soil Laboratory Network (GLOSOLAN) was established in November 2017 within the framework of implementing Pillar 5 activities, which concern the harmonization of methods, measurements and indicators for the sustainable management and protection of soil resources.

For more information on the Global Soil Partnership, please visit http://www.fao.org/global-soil-partnership/about/why-the-partnership/en/.

For more information on Pillar 5 of the Global Soil Partnership, please visit http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/en/.

For more information on the first GLOSOLAN meeting, please visit http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/glosolan/en/.

GLOSOLAN aims to 1) make soil information across laboratories, countries and regions comparable and interpretable, 2) build a set of agreed harmonization principles, 3) improve quality assurance (QA) and quality control (QC) of soil analyses, and 4) promote information and experience exchange to develop capacities wherever needed. The establishment of the GLOSOLAN and the definition of Pillar 5 activities is based on the assumption that **soils can only be managed sustainably at the global level if sufficient, reliable and comparable information is made available to all actors involved**. **Comparable and useful soil information will only be attainable once laboratories agree to follow common standards and norms.**

This survey was launched to address a lack of information concerning the practices of soil laboratories around the world. This information was necessary to determine a roadmap for the GLOSOLAN, and determine its priority actions.

In order to identify post-2018 activities of the global and the several Regional Soil Laboratory Networks (RESOLANs), a survey was developed by the GLOSOLAN Working Group, using the survey developed by the Asian RESOLAN (SEALNET) as a baseline.

The survey was created and hosted on the 'SurveyHero' website (www.surveyhero.com). The GSP Secretariat made it accessible between the 4th of February and the 30th of March, 2018 and any interested laboratory manger could participate. To maximise the number of participants, GSP focal points and the participants from the first GLOSOLAN meeting were asked to forward the survey invitation to their national laboratories and contacts.

During and after the survey, the individual surveys were stored in the server of the GSP Secretariat, accessed by a limited number of authorised FAO staff and treated according to the GSP Soil Data Policy. Individual surveys are non-public.

To ensure data confidentiality, before being forwarded to the GLOSOLAN working group, survey replies were made anonymous both by changing the name of each laboratory to a single code number, and by aggregating the results of each lab with results of the laboratories for the same region.

This report presents and discusses the results of the first GLOSOLAN online survey at the global and regional level. This is the first soil laboratory survey ever made at such a large and international scale.

2 Structure, dissemination and evaluation of the survey

2.1 Structure of the survey

The survey was organised into 11 Sections. A short justification/list of objectives for each section is provided here:

- **General information of the soil laboratory**: to identify the responding laboratory and provide a unique code to avoid duplicate answers and to make future monitoring possible.

- **Affiliation to an existing soil laboratory network**: to identify potential collaboration with existing networks during the establishment and implementation of RESOLANs and GLOSOLAN.

- **Staff qualification and performance:** (1) to estimate the size and capacity of the soil laboratory, (2) to identify the employee expertise, educational gaps or training needs, and (3) to assess the internal QA/QC of a laboratory, as well as the overall laboratory performance in terms of Good Laboratory Practice (GLP).

- **Infrastructure of the laboratory**: to identify the current status of soil laboratories, and check if the infrastructures have the required characteristics to perform good quality data according to international standards.

- **Clients of the soil laboratory:** (1) to determine the institutions and citizens interested in collecting data about soils, (2) to understand the local role of each laboratory in the network, and (3) set the basis for increasingly standardized interpretation of laboratory results.

- **Analysis performed by the laboratory:** participant laboratories in the survey were asked about the methods used to assess a set of 40 soil chemical, physical and biological parameters. This huge dataset has provided a first overview of the analytical procedures currently performed by the laboratories throughout different regions worldwide. It can be used to assess the needs and possibilities for achieving worldwide standardization and harmonization of soil analysis methods.

- **Special focus on pH in water**: a detailed investigation on all the steps of the analytical procedures. Indeed, not only is pH one of the most basic soil characteristics, it is also one of the simplest and cheapest soil analysis methods . Consequently, setting up a standard method for soil pH analysis can have an immediate impact (i) for improving a global soil management and (ii) for deciding procedures of standardization and harmonization inside RESOLANs and GLOSOLAN.

- **Special focus on organic carbon**: a detailed investigation of the steps of the analytical procedures used, and assessment of the extent to which procedural differences can explain worldwide differences in results. In the near future, harmonization of analytical procedures will aid the process of improving the Global Soil Organic Carbon Map (GSOCmap) prepared and launched by the Global Soil Partnership in December 2017, which is highly needed by many international institutions.

- **Quality Assurance and Quality Control (QA/QC)**: this section included questions on the use of control samples and reference materials. Identifying the current practices can help to determine the quality of results currently provided by the laboratories, and also identify the needs to reach a minimum level of worldwide quality.

- **Soil laboratory certification and accreditation**: to assess if each individual laboratory quality has been previously evaluated and certified. Ultimately, this would serve GLOSOLAN to both incorporate and complement the work of previously established systems.

- **Expectations for GLOSOLAN**: this was an open question that allowed respondent to make suggestions for the future of the program.

The first 10 sections contained questions numbered from 1 to 73 (the survey is available in Annex 1). Most of them were in a closed format but also provided spaces for answers that deviated from prescribed answer options. Some questions aimed to cross-check information that concerned critical aspects of soil laboratory functioning.

Note that question n°38 requested a detailed description of existing laboratory procedures for 40 different parameters. Consequently, the survey contained in reality 113 questions, including a final question about expectations of GLOSOLAN (which did not receive a specific number in the survey).

2.2 Outreach and participation in the survey

Statistics on outreach and participation surrounding the survey are presented here:

- 732 views
- 293 forms started to be completed (40% of the views). But several respondents did not finalize the completion during the first visit and tried to complete it during a second visit. But this was not possible, so they had to start again from the beginning what has seemingly discourage a large number of people to answer all questions.
- 111 forms were finally completed and were used to realize this survey interpretation.

Results came from 66 countries. The top ten responding countries were: Thailand (6 respondents), Philippines, Portugal, Germany, Belgium (5 respondents each), Croatia (4 respondents), UK, Pakistan, France and Mozambique (3 respondents each).

Preliminary comments

When analysing survey results of this nature, two main concerns must be taken into consideration:

- Firstly, the quality of the answers. On one hand, some questions could be unclear or qualitative in such a manner that different people will interpret them in different ways. Furthermore, people might be tempted to provide the answer they think the investigator expects, making the answer generally different or slightly improved from reality.

- Secondly, the representativeness of our sample. The survey was completed on a voluntary basis and, consequently, the laboratory sample is not representative of all existing soil laboratories worldwide. In this case, it was hypothesized that responding laboratories would also contain the highest motivation to participate in GLOSOLAN and RESOLAN. As these laboratories have the highest probability to join RESOLANS & GLOSOLAN, they will be the first bricks to build the international network. Thus, it is worth to have a detailed picture of these motivated laboratories and lab managers.

Whatever the limitations of our survey, this is the first survey ever made about soil laboratories at such a large scale. The data set compiled through this survey has an inestimable value for the international community and for GLOSOLAN to set its work plan. In this regard, the decision to focus the data analysis on the identification or priority activities to propose for implementation at the 2^nd^ GLOSOLAN meeting (28-30 November 2018) was made. The authors hope that the readers will be able to forgive them for analyzing and interpreting some data only preliminarily, as is the only possibility at this stage, and sends sincere thanks to all lab managers completing the survey for their time and contribution to GLOSOLAN and RESOLANs.

2.3 Survey evaluation

Responding laboratories were grouped by geographical regions (Africa, Asia, Europe, America, Near East and North Africa) as showed in Figure 1. To note that:

- Because only one survey was completed by North America and the Pacific, these two regions were not mentioned in this report and their answers were associated to America and Asia, respectively.
- Because of the interest of the European Soil Partnership and the Eurasian Soil Partnership to work together in GLOSOLAN, their contribution to the survey was compiled under Europe;
- Because the Central America, Caribbean and Mexico Soil Partnership, and the South America Soil Partnership are work together in GLOSOLAN as 'Red Latinoamericana de Laboratorios de Suelos' (LATSOLAN), their contribution to the survey was compiled under America.

A summary of the replies to the survey provided by each region in the Global Soil Partnership as well as their geographical consideration in this report is provided in Table 1.

Figure 1: Geographical regions considered in the survey analysis

Table 1. Countries' participation in the survey

GSP Regions	Number of countries that answered the survey	Total number of responses per identified region	Classification of the regions in this report
North America Soil Partnership	1		
Central America, Caribbean and Mexico Soil Partnership	10	17	America
South America Soil Partnership	6		
Africa Soil Partnership	17	17	Africa
Near East and North Africa Soil Partnership	9	9	NENA
European Soil Partnership	46		
Eurasian Soil Partnership	6	52	Europe
Asian Soil Partnership	15		
Pacific Soil Partnership	1	16	Asia

3 Results and discussion

Section 1: General information of the soil laboratory (question 1-8)

The answers to these questions are confidential and cannot be presented or commented.

Section 2: Affiliation to an existing soil laboratory network (question 9-10)

At a global scale, most of the laboratories (59%) were not yet affiliated with an existing soil laboratory network. The remaining 41% of them stated to be affiliated to an existing network. Of these, two out of three stated to be affiliated to a national soil laboratory network; only one out of three laboratories reported to be affiliated to an international network.

Some regional variability was observed:

- NENA: no respondent laboratory was affiliated with any soil laboratory network,
- Asia: 5 laboratories stated to be affiliated to an existing networks;
- America: 8 laboratories stated to be affiliated to an existing networks;
- Europe: 25 laboratories stated to be affiliated to an existing networks;
- Africa: 10 laboratories stated to be affiliated to an existing networks.

To conclude, this section enquired whether laboratories collected national data on agricultural or forest soils. Most of laboratories (46%) collected national data on agricultural soils, 27% of them collected data on both agricultural and forest soils, and only 5% of them mainly located in America and Europe worked on forest soils only. Surprisingly, 21% of the laboratories stated not to collect either agricultural or forest soils data.

Section 3: Staff qualification and performance (question 11-16)

Number of employees (question 11) & Employee contract type (question 12)

According to the number of employees (both permanent & temporary contracts), the laboratories were classified as small, medium and large, i.e. <=10, 11-50, >50 employees. Over half of the laboratories completing the survey (53%) were small, 41 % were medium and only 6 % of them were large and located in America and Europe.

If large laboratories are taken out from the calculation, the average number of permanent employees is 9.1 (+/-7.6 as the standard deviation, n= 104). Temporary contracts represented an average value of 2.6 (+/-2.5 as the standard deviation, n= 94). It appeared that nearly all the laboratories were employing temporary staff, and this temporary staff can represent a significant proportion of total staff: in average around 20% in Africa and Europe, 25% in NENA, 35% in America and up to 70% in Asia.

Regional differences also existed in the total number of staff: small laboratories with 9 staff members on average were found in America, laboratories with on average 11 to 15 staff members were found in Africa, Europe and Asia, and laboratories with 23 staff members on average were found in NENA countries (see annex 2).

Formal education, training and experience of laboratory staff (question 13, 14, 15)

In 72% of the laboratories completing the survey, half or more of all employees received a formal education, while within 24% of labs the majority of the staff did not. Still, 4% of the labs did not answer this question. Significant differences in average situations were noted in Africa (low education concerned 42% of the laboratories) and in NENA (low education level was never mentioned).

Regarding the percentage of employees trained to perform analytical work (question 14), 75% of respondent laboratories counted half or more of their employees as being trained to perform analytical work. A major lack of training to perform analytical work was identified in America (in one out of three laboratories the majority of the staff was not trained). When looking collectively at the percentage of employees educated, trained or having experience specifically in "soil" analyses (question 15), the results show that most laboratories (82%) have such employees.

Existence of a training programme for the laboratory staff (question 16)

One third (36%) of respondents did not have a training program to regularly improve the skills of their employees. A particular high need for the establishment of a regular training program was identified in Africa and America, where half of the surveyed laboratories did not offer regular trainings for their staffs.

Discussion and suggestions

The assessment of the number of employees with either a permanent or a temporary contract can provide information on the general staff qualification inside the laboratories. It can be assumed that a high percentage of temporary staff increases the risk of inconsistent practices when performing analytical procedures. Data showed the existence of a significant number of laboratories with a high ratio of either temporary, low educated or untrained staff on soil analysis or any analytical work.

While assessing the importance of educational program designed to maintain or to increase staff's expertise in analytical activities, it was observed that a large number of laboratories were regular and professional trainings are not organised. In those laboratories where trainings are organised, it is unclear how the responding people understood the word 'training', which could also be considered as the provision of basic information to new staff. In the near future, it will be important to define what trainings refer to and identify the laboratories that are already providing them to their staff, and that could be available to train other laboratories.

***As a conclusion, it appears that probably the current staff qualifications are not high enough to guarantee good quality analytical results.** Thus, complementary information should be collected to get a better picture of the current situation. Such complementary survey could be conducted by the RESOLANs because of their better understanding of national diversity. This complementary survey has to be made under the coordination of GLOSOLAN in order to ensure that the data collected can be compared between regions. Moreover, training programmes should be developed by GLOSOLAN (to have a worldwide standard) and regularly conducted at regional level: the most qualified laboratories could organise and host such trainings for the other laboratories in their region. Such trainings could also be a highly effective way to promote technical and scientific cooperation between the highest qualified laboratories in GLOSOLAN.*

Section 4: Infrastructure situation (questions 17 to 29)

Soil samples reception and storage (questions 17-20)

Almost all surveyed laboratories (92%) stated to have a sample reception area. The majority of them (86%) store dried sieved soil samples at room temperature in a proper storage room, on a laboratory cupboard, tray, soil bank or other at an average room temperature of 25°C. Most laboratories (71%) stored soil samples in plastic containers, very few used (5%) sealed glass, and the rest of respondents used both or other storage materials like paper bags and zip bags. Only 38% of the laboratories had a cold room with a constant storage temperature of 4°C, this was mainly found in Europe (62%). A very low number of laboratories stored their samples in a dark room, besides those in Europe (21%).

Laboratory safety (question 21-23)

The survey indicated a general adoption of storage and labelling procedures for reagents. 86% of laboratories have one or more rooms dedicated to the storage of reagents, with reagents organized by groups (acids, bases, flammable, highly toxic compounds and compressed gases), with sections labelled accordingly and properly. Additionally, 74% of all laboratories have labels indicating the receipt, and the opening/disposal dates of all chemicals/reagents. Laboratories generally (67%) have a system to check the receipt and opening dates of chemicals/reagents but one out of three laboratories did not have such a system yet. Those systems were particularly missing in laboratories in America and Africa.

Facility monitoring (question 24)

Temperature and humidity monitoring in sensitive areas (e.g. balance room, analytical room) is done hourly or daily by only 39% of the responding laboratories. This situation is similar in all regions.

Laboratory facilities (question 25-27)

A large majority of laboratories (93%) have a room dedicated to the preparation of soil samples, 75% of them have a room dedicated to the storage and use of balances, and 80% have a specific area dedicated to glassware cleaning.

Water in the laboratories (question 28-29)

Most of the respondents (46%) used deionized water followed by distilled (29%) and double distilled water (8%). Tap water is used by 6% of laboratories in Africa.

In addition, 36% of the laboratories did not test the EC of the water used in the laboratory.

Discussion and suggestions

It appears that the infrastructure and organization within soil laboratories do meet minimum requirements, so these do not seem to be limiting factors to the quality of the analytical results. However, in case of further investigation, it could be useful to determine the extent to which Good Laboratory Practices (GLP) are implemented and used on a regular basis.

Section 5: Clients of the soil laboratory

Main client type (questions 30-31)

The majority of lab clients were public entities like research institutes, government departments and farmers (over 70 to 80% each), followed by NGOs and fertilizer industry (over 40% each) and other clients like industries and private companies (12% each).

A majority of clients (83%) requested advice on the interpretation of their soil tests.

Data reporting and interpretation (question 32-34)

The results of soil tests were commonly reported both in hard copy and electronically (59%); some respondent laboratories choose to report either in hard copy form (21%) or in electronic form (15%). In most cases, soil laboratory reports are signed by the laboratory manager (42%) or have multiple signatories (24%). Alternatively, the head of the department (12%) or the technical staff (6%) may sign the report.

For the majority of soil laboratory reports (51%), an interpretation of data results was included in the analysis as a standard, or was given by the laboratory upon request of the client (33%). Only 15% of respondent soil laboratories stated that no interpretation was provided.

Discussion and suggestions

Nowadays, most of the information available about soils comes from analytical results (no more direct profile observations, and not yet enough remote sensing observations from satellite or drone images). Thus, it was necessary to have a global view on the people/institutions that are investing in soil analysis. Since the majority of the clients were public entities (e.g. research institutes, NGOs and governmental departments), the quality of soil analysis is expected to have a large impact on decision-making and/or science. It is important to consider that some of these institutions would perhaps be willing to provide financial or technical support to GLOSOLAN/RESOLANs.

Interpretation of the results was requested for a large number of analyses and should consequently be included in the standardization and harmonization that GLOSOLAN would like to achieve.

Sections 6: Analyses performed by the laboratory

Purpose of the analyses (question 35-37)

Most of the laboratories made analyses related to soil chemistry (98%) and soil physics (76%): a minority did it in relation with soil biology (23%) and 'other' characteristics (15%).

At global scale, analyses were firstly used for fertilizer recommendations (76%), secondly for soil classification (65%). At the regional scale, 56% of Asian laboratories did not perform analyses for soil classification and a majority of Latin-American and European laboratories did not perform analyses for fertilization.

The average annual number of samples can be considered an indicator of the level of laboratory activity.

According to the number of samples, laboratories were classified into small, medium and large, i.e. <=1 000, 1 000-6 000 , >6 000 samples annually. 66% and 42% of respondent laboratories reported to analyze less than 1000 samples for soil classification and fertilizer recommendations, respectively. Large amounts of samples (> 6 000/year) for fertilizer recommendations were more commonly reported (18%), compared to the sample amounts analyzed for soil classification (7%).

The distribution of small/medium/large laboratories varied amongst the different regions. One in four laboratories in Africa and Asia, and one on three in Latin –America can be considered as large (> 6 000 samples/year for fertilizer recommendations).

The results generally were in accordance with the estimated laboratory size based on the number of employees (see Section 3: Staff qualification and performance).

Discussion and suggestions

It will be up to the RESOLANs to take diversity of lab characteristics into account when developing their work plan.

Soil pretreatment (question 39-41)

Five types of sample pre-treatment are generally considered: drying, crushing, sieving, dividing and milling as reported in ISO 11464. This international standard was the most common method of soil pretreatment reported globally, while 17% of the other respondent laboratories stated to use a mix of established protocols from literature, further international standards (ISO 9000, ISO 11465), and inter-organizational standards. The lack of standard pretreatment was 36% at global level and was particularly high in laboratories affiliated with Asia, America and Africa, where no pretreatment was applied in 83%, 50% and 47% of the laboratories respectively. This high rate is very surprising, so it must be noted that it could result from a misinterpretation of our question.

Respondent laboratories stated to dry their soil samples, 55% air dry, 32% oven dry, 8% use both approaches. Very few laboratories (3%) reported chemical dry, dry freeze, and flat heater. Oven dried samples are mainly used for analyses in laboratories in Europe (42%) and America (38%). Those using “oven dry” reported a range of temperature conditions from 30°C to 105°C, most of the respondents (46%) who use “oven dry” did it at 40°C. This procedure was especially well established amongst laboratories in Europe (57%), whereas temperature ranged broadly between laboratories in other regions.

Samples grinding was mainly done manually (50%), by machines (29%) or both (12%). Grinding methods were found to be most diverse amongst laboratories from Europe, where 12% of laboratories reported to use other methods e.g. agate ball mill, colloid mill, and jaw crusher.

The most common sieve was the 2 mm sieve (79%); 0.5 and 0.2 mm sieves were used by only 4% and 2% of the laboratories respectively. As for the grinding method, laboratories in Europe reported a wider variety for sieves used for the soil sample pretreatment in the category *Others*, e.g. the usage of several different sieves ranging from an 8 mm sieve to 53µm, depending on the type of analysis, the type of the soil sample (mineral or organic soil), and the sample amount/sample weight to be analyzed.

Discussion and suggestions

The high rate of absence of pretreatment in some region was very surprising. This suggested a misinterpretation of the survey question; most probably many laboratories had to prepare and process the samples before the analysis but they did not call it a ‘pre-treatment’. From the analysis of the results it appeared that a lack of standard pretreatments can also be a reason for variability in the results.

The analyses performed by the laboratories (question 38)

For a list of 40 parameters, it was asked if these were analyzed, how many analyses were performed annually, what was the general procedure and if that was a standard method, for which purpose it was used and if the method was accredited/certified. Even with a limited list of basic questions, a wide diversity of answers was obtained. This diversity represented already an information about the existence of a large diversity of situations. In this report, only the most important aspect to report at the second GLOSOLAN meeting were presented. However, more detailed analysis will be performed and provided as soon as possible.

Points for consideration are: (i) the parameters that were analyzed by the largest number of responding laboratories and (ii) the parameters that were analyzed more frequently worldwide. The 'top10' analyses identified keeping these two criteria into consideration are presented in Table 2.

Table 2: Soil parameters analyzed by the largest number of responding laboratories (list on the left side) or analysed more frequently ((list on the right side).

Parameter	Number of laboratories	Parameter	Number of analyses
pH in H2O	88	Available P_ other	335 480
Electrical conductivity (EC)	83	Organic Matter	272 927
Total Nitrogen	81	pH in H2O	239 293
Texture analysis	80	pH in KCl	224 857
Organic Carbon	78	Exch. K - NH4O-Ac	221 608
Organic Matter	72	Exchangeable acidity	214 755
Micro elements	67	Organic Carbon	189 948
N-NO3 and N-NH4	63	Texture analysis	180 213
pH in KCl	61	Micro elements	174 230
Trace elements	60	Electrical conductivity (EC)	166 600

As shown in Table 2, pH in H2O and in KCl, Organic Carbon , Organic Matter, Electrical conductivity (EC) and Texture, are the most frequently and wider analyzed.

Unfortunately, the large set of analysis and procedures information collected through the survey could not be reported in this document. However, they will be analyzed in the near future in collaboration with RESOLANs.

Discussion and suggestions

It was very surprising not to see Phosphorous and Potassium in the list of the most frequently and widely analyzed parameters. These two parameters are indeed quite important to assess the soil fertility. Similarly, it was surprising not to see Cation Exchange Capacity (CEC) listed, which is necessary to estimate fertilizer application rates or fertility potential/capacity. This could result from mistakes when filling the survey: perhaps wrong answers have increased the importance of some parameters (that consequently appeared in the ‘top 10’) and have simultaneously decreased the importance of other parameters. It could be useful to organize a specific survey to run in the regions (RESOLANs) to have a better estimation of the number of analysis performed by a larger sample of laboratories in order to confirm or not the list of the `top 10’ parameters.

Moreover, it seems necessary to include these six parameters in the effort of standardization and harmonization, due to the fact that the laboratory managers that have the highest motivation to join GLOSOLAN and their clients will likely be interested in getting higher quality and standard results at a faster pace.

Section 7: pH in water (question 43-46)

Soil:water ratio for preparing the soil suspension

A large majority (82%) of laboratories used a ratio by weight (g soil/g water), the others (18%) used a volume/volume approach. The latter were more frequent in Europe (29%).

Laboratories reported a wide range of soil solution ratios from 1:1 to 1:10 soil-water solutions. In the majority, ratios of 1:2.5 (32.1%), 1:5 (35.7%), and 1:1 (14.3%) were reported.

Looking at the regional level, 1:2.5 was preferred in Africa and America (53% and 38% respectively), 1:1 was preferred in Asia (56%), 1:5 in Europe (42%).

Stirring and settling times

Respondent laboratories also reported a very broad range of stirring times, from 1 to 120 minutes. The most frequent stirring times were 30 minutes (20%), 60 min (19%) followed by 5 min (14%) and 10 min (8%).

The largest regional variation was found in America, where 5 min was most common (38%).

An even larger range was reported for the sample settling times after stirring time: from 0 to 1200 min. The most frequent settling time was 60 min (19%) followed by 10, 30 and 120 min (11% each). The largest regional deviation from average was found in Europe where 60 and 120 min were the most frequent (21% each).

pH reading

To read the value of pH, the electrode was located in the clear supernatant for 48% of the respondents, and located in the soil settled at the bottom for 16% of them. One out of four laboratories stated to use other procedures, e.g. measuring the pH while stirring (6%), in the stirred soil suspension (16%), and in the soil pulp (1%).

Comment: even for measuring a parameter as simple (on a technical point of view) as the pH, a large variability was observed in executing four compulsory steps in the analysis resulting on a very large variability between the laboratories, even when the laboratories are located in the same region.

Section 8: Carbon content (question 47-50)

Removal of living roots

Complete removal of roots from soil samples before soil organic carbon measurement is a prerequisite. Living roots removal was shockingly done by only 65% of the laboratories. All the regions had very similar answer to that question. Removal was done either manually (37%), by sieving (16%) or both methods (4%). Living roots were not removed in 38% of the laboratories in America, 29% of the laboratories in Africa and 21% of the laboratories affiliated in Europe. Standardization of sample pre-treatment therefore seems necessary.

Soil fraction and mass

Sieving size is a critical parameter; reported sieve-use involved mainly 2 mm sieves, used by half of the laboratories (47%). The other half used 0.5 mm (20%), and sieves other than those mentioned in the survey. These included the usage of several different sieves ranging from 0.25 mm to 25 µm sieves depending on the type of analysis, the type of soil sample and the sample weight.

There was a broad range of soil masses used for carbon analyses reported, ranging from 0.0025 g to over 500 g, the most common (36%) soil mass range was between 0.2 g to 5 g, and nearly the same proportion of laboratories (28%) used a range of soil masses depending on the soil type.

Analytical methods

Walkley & Black was the most common method used by 62% of laboratories; combustion was used by 26% of the laboratories and 12% used other methods (Tyurin, Heanes, etc.).

If the different regions are considered, Europe is the only Region where the Walkley and Black method was used by a minority of labs (15%) and dry combustion method was more frequent (26%).

Details on procedures for the Walkley and Black method

Another critical parameter is the ‘potassium dichromate: sulfuric acid’ ratio. This ratio was 10:20 for 34% of total number of laboratories and 10:25 for only 5% of them. Note that a 10:10 ratio was used by 19 % of the laboratories who replaced K-dichromate by K-permanganate. This change could have a significant impact on the analytical results because no sulfuric acid is used with K-permanganate, making the reaction temperature lower.

Comment: even if procedures for carbon content measurement was smaller compared to those for measuring soil pH, this variability can have large consequences on the final result. Absence/presence of root removal will most probably have the largest impact, but even differences in fraction sizes and ratio of potassium 'dichromate: sulfuric acid' could have an important impact.

Section 9: Quality control and quality assurance (question 51-65)

Standard operational procedures (SOPs) and logbooks

Most soil laboratories (91%) stated to have and use SOPs, however 4% reported they did not, while 3% reported to have SOPs but not use them. About 39% of the laboratories from Asia did not have and use any SOPs; this high rate is surprising and could result from a misinterpretation of our question. Mostly analytical SOPs are available in the rooms where analytical tests are carried out, however in 11% of all surveyed laboratories and 39% of surveyed laboratories in Asia, SOPs were not available in that room. SOPs were written in the national language for 39% of the laboratories, in English for 24%, in other official UN languages (English, French, Spanish, Chinese, Russian and Arabic) for 19%, both national/UN official language in 10% of the laboratories. Looking at the regional level, laboratories in Europe most commonly used SOPs written in the national language (65%), whereas English written SOPs were rarely used. Laboratories in Africa and NENA for the majority reported that used SOPs were written in English. In America 63% of laboratories used SOPs written in other UN official languages (mostly Spanish).

Survey responses for investigating the existence of "Maintenance log books" for instruments (balance, spectrometer, etc.) found that only 68% of laboratories used such books yet. "Result log books" near each instrument were available in only 59% of the laboratories.

Instrument calibration

Survey participants also reported differing frequencies of calibration for the balances in the soil laboratory, from yearly to daily. In this regard, the results showed that good laboratory practices (GLP) still need to be implemented as a standard practice. Generally, it is assumed that the higher the calibration frequency for the used balances, the better the performance of the laboratory. However, only 25% of all surveyed laboratories reported daily calibration. On the contrary, another 25% stated to calibrate the balances only once per year. Calibration of balances was best established in European laboratories, with a high percentage of daily (29%) and weekly (13%) calibration, and internal calibration before each use/set of measurements (10%). The majority of laboratories in Africa, Asia and America reported yearly calibration; laboratories in NENA reported monthly (50%) and quarterly (50%) calibration.

Analytical batches

33% of the respondents stated that the average number of samples per analytical batch was dependent on the analytical method, the analysed parameter, and the rate at which samples were received in the laboratory, giving no explicit of number of samples (3%) or giving an explicit variable range (33%). A very small portion of respondent laboratories (5%) did not include a “blank” sample of the extracting solution in each analytical batch.

Internal/quality control samples

Internal control samples were also widely used amongst laboratories (85%), only 15% of participants reported not using them. However, at the regional level an insufficient utilization of internal control samples was observed in Asia and Africa where 39% and 24% respectively did not use such samples. The number of used internal control samples per analytical batch ranged from one to ten (70%), with the majority using less than six.

Most laboratories (83%) included quality control samples, only 17% of the laboratories did not. As for internal control samples, quality control samples were not widely used in Africa and Asia, where 29 and 28% of the laboratories did use such samples in an analytical batch, respectively. Internal Reference Material (IRM) and standard reagent made up the majority of material used for quality control samples, each representing about a third of the reported answers. Certified Reference Material (CRM) is overall less commonly used in laboratories (25%), particularly in Asia. Internal control samples were used by 34% of the responding labs to track soil laboratory performance. There was a wide range of responses for how frequently laboratory performance is checked, ranging from daily to yearly. More than half of the laboratories used internal standards to check performance at least once per week or more frequently. The acceptance limits used to consider the analysis of an "internal control sample" or "quality control sample" reproducible reported as follows: 5% acceptance limit (25%), 10% acceptance limit (32%), and 15% acceptance limit (3%). A majority of 80% of respondent laboratories would reanalyse the batch of samples when results from "internal control samples" or "quality control samples" fall out of the acceptance limits. Some laboratories (9%) indicated they would only reanalyse the analytical data near the control, in 5% of laboratories responded no action is taken, and 1% of the responding laboratories stated the analytical data would be corrected. No consequence can be drawn from Africa, Asia and America at 6%, 11% and 6% respectively.

Section 10: Soil laboratory certification and accreditation (question 66-70)

Participation in proficiency tests/inter-laboratory comparisons

Most laboratories (81%) responded that they participated in proficiency tests or inter-laboratory comparisons; with only 19% not participating in those activities. Generally, the survey results showed that the participation in those activities was highest for laboratories in Europe (92%). In Africa, Asia, America and NENA approximately one third of surveyed laboratories did not participate in proficiency test or inter-laboratory comparisons. Those laboratories that answered yes, reported participation at international (37%) or national (33%) level, with only 13% of them participating at both levels. A small majority of laboratories in Africa (59%) and Europe (48%) participated on international level, whereas laboratories in Asia, America and NENA mostly participated on the national level. A few laboratories stated to be in the planning phase towards participation in proficiency tests/inter-laboratory comparison. A small majority (23%) of laboratories indicated that they participated in proficiency tests or inter-laboratory comparisons at least once a year. 14% of all surveyed laboratories, and one in four laboratories in America reported to participate less frequently (every 2 to 5 years) in those activities.

Accreditation/Certification

More than half of all participants in the survey were not accredited or certified (54%), those that were, were mostly certified by ISO 17025 (28%), and to a much lesser extent ISO9000 (3%), other responses included further accreditation/certification by e.g. ISO 9001, ISO 10012, ISO 17025, or national standards. A few laboratories from Africa, Asia and America stated to be in the process of accreditation/certification. Regarding the status of certification/accreditation of analytical procedures used in the laboratories (see Table 3**Error! Reference source not found.**), only one in three laboratories got certified/accredited. 23% of all surveyed laboratories did not use certified analytical procedures yet and for the majority of laboratories no information on the status of certification/accreditation was available at all. These results indicate an urgent need for the implementation of a certification as well as a QA/QC system using ring tests or inter-laboratory comparisons.

Table 3: Status of certification/accreditation of analytical procedures used in the laboratories

Answer option	Africa	Asia	America	Europe	NENA	Global
Accreditation	29%	33%	17%	50%	44%	33%
Non certified	24%	20%	33%	27%	12%	23%
NA	47%	47%	50%	23%	44%	44%
Total	100%	100%	100%	100%	100%	100%

Within a good majority of laboratories taking the survey (71%), a data library was maintained. However, about half of the laboratories in Africa and Asia did not collect their data using a data library yet.

Section 11: General comments & Expectations on GLOSOLAN

Overall expectations from respondent laboratories on GLOSOLAN can be summarized as follows:

- Establishment of a training program for laboratory staff (technical staff/management staff);
- Improvement/enhancement of laboratory infrastructure, equipment, facilities;
- Support laboratories in certification/accreditation process for used instruments, laboratory procedures, etc. following international standards (e.g. ISO); and
- Development and promotion of a certified GLOSOLAN soil laboratory QA/QC system including a staff training to improve QA/QC.

In addition to general expectations on GLOSOLAN, the needs of soil laboratories were different from one region to another, see Table 4.

Table 4. Summarized specific laboratory needs in the RESOLANs

Region	Specific laboratory needs
Africa	▪ Guidance for managing the disposal of laboratory waste properly ▪ Methodology catalogue that includes methods which are not harming the environment and poses no health risk for staff ▪ Participation in inter-laboratory tests/proficiency tests on national/international level ▪ Regular maintenance/calibration of instruments ▪ Innovative analytical methods ▪ Improvement of the internal laboratory control and enhancement of the use of logs
Asia	▪ Data management system ▪ Enhanced collaborations with academia, industries, governmental institutions ▪ Innovative analytical methods ▪ Capacity building (e.g. resource mobilization to hire trained and qualified soil analysts) ▪ Acquisition of internal quality control samples (for batch analyses)
America	▪ Innovative analytical methods ▪ International cooperation ▪ Training and capacity building
Europe	▪ Improvement of the experience exchange on national/international level ▪ Participation in international ring tests ▪ Certification of used instruments and procedures after ISO ▪ Participation in inter-laboratory comparisons ▪ Reference materials ▪ Acquisition of certified materials as reference standards in analytical procedures ▪ Standardized data repository
NENA	▪ Improvement of the experience exchange on national/international level ▪ Revision and adaption of existing analytical methods following ISO standards ▪ Acquisition of internal quality control samples (for batch analyses)

4 General discussion

Most of our knowledge concerning soils, and the impact of human management on them, come from laboratory analysis. The existence of soils within one common, global ecosystem creates the need for global management of our limited soil resources, a practice that will require data collected from any laboratory in the world to be comparable with data collected in any other laboratory. In other words: **for a soil sample sent to different laboratories, all should attempt to produce the same analytical results, within a given range of uncertainty!**

From everyday laboratory experience, it is known that reaching such a goal cannot happen by chance, but requires constant effort. If laboratory managers and their staff do not make this effort, different results are likely for the same soil samples. Differences in analytical results can be monitored during a ring test (also called 'proficiency test') but conducting such a test at a worldwide scale is a challenge for the moment because of (i) customs/quarantine rules concerning soils' exportation and (ii) the difficulties in obtaining sufficiently large quantities of control samples (reference material, etc.).

As organising a global ring test was not possible in the timeframe, nor resourced, **GLOSOLAN decided to launch a survey to document the current procedures and practices of soil laboratories in order: (i) to identify possible sources of analytical result variations, and (ii) what efforts could be undertaken for achieving the desired objective** (i.e. 'send one sample to many labs and get one result +/- known uncertainty').

To achieve standardised and harmonised analyses it is known that the following factors need to be controlled: standard operating procedures (SOPs), equipment, staff qualifications, internal quality control (IQC), external quality assessment (EQA) and certification.

Based on the results of the survey, it was possible to suggest milestones for each of these six factors on the GLOSOLAN roadmap to advance excellence in soil laboratories for more efficient and effective world-wide soil management.

4.1 Standard Operational Procedures (SOPs)

When working with laboratories, the first factor explaining differences in analytical results are the differences in analytical procedures. The question 38 that concerned 40 parameters demonstrates that these differences in analytical procedures can be very large for complex procedures (like phosphorous), but even for simpler procedures (like pH). Consequently, the first priority of GLOSOLAN should be the development of SOPs that could be adopted worldwide. But worldwide adoption seems difficult, if not impossible. The existing barriers to the adoption could result from:

- laboratory owners/managers that would have to buy, maintain and calibrated new equipment (glassware, chemicals, etc…);

- laboratory staff that would have to change working habits and increase their competences; and

- clients that might not want to use data obtained with different methods, as these data can hardly be compared with older ones.

As it is certain that all laboratories will not adopt a single SOP (at least during this first round of discussions), it is necessary to select for each parameter a SOP that fulfil one or several of the following criteria:

- already used by the highest number of laboratories,
- already represents the highest number of analysis done worldwide

- already is an international SOP that was validated
- could be adopted by nearly all the participating laboratories in a given region
- could be adopted at least by the reference laboratories of each country
- other

Note that for different SOPs, it could be necessary or more efficient to use different criteria.

If all laboratories do not adopt a single SOP, thus different procedures will be used to characterise a given soil characteristics. **Consequently, when selecting a SOP it seems also necessary to think about possible harmonisation of its results with results obtained by other methods, i.e. work also on the possible way of converting results to make them comparable.**

As a conclusion, for each SOP it will be necessary to answer, at least, the following questions:

1. What is important to standardise for this particular method?
2. At what level can the decision be made: RESOLAN or GLOSOLAN?
3. What is an achievable objective?
4. What can be the drivers or the facilitators to reach this objective?
5. What are the barriers that makes it difficult to reach the objectives?
6. How can a sufficient level of standardisation be reached?

In the context of this report, it is not possible to answer these questions as it needs a direct discussion between laboratory managers.

4.2 Equipment and infrastructure

Equipment and infrastructures concerns the 'environment' in which the analyses are performed (see section 4, question 17 to 29). As for the SOPs, this issue can be examined by trying to answer to some simple questions:

- What needs to be improved?

According to the answers to our survey, it seems that in most of the laboratories, the equipment and the infrastructures have generally good quality: they have special rooms for soil preparation and storage, good conditions for soil storage and also for the storage of chemicals, special rooms for the specific equipment and in most of the cases the quality of water seems correct. Consequently in most of the laboratories, the equipment and infrastructure did not appear to be factors that could limit the quality of the analytical results.

- At what level can the decision be made?

If improvement is necessary or recommended, it can be decided and organized only at the laboratory or at national level.

- What is an achievable objective?

The objective could be to get equipment and infrastructure that follow the general recommendations from RESOLAN and GLOSOLAN in order to have similar characteristics and similar influence of the equipment and infrastructure on the analytical results and their variability, as well as the safety and working conditions of the staff. For example, if pH is considered, one of the most commonly analysed parameter, an achievable objective would be to have all laboratories using equipment and infrastructures that have similar characteristics (pH meter, probes, but also controlled room temperature, etc.).

- Drivers/facilitators to reach the objective?

Reaching the objective would be facilitated by the existence of a platform of discussion for laboratory managers to exchange information about instruments' qualities (reliability, cost of running the instruments, specific need, etc.), building organization, sample storage, *etc*. It is also recommended to set up a data base to keep a record of all those technical information that could be used by any routine or research laboratory that wants to do soil analysis.

- Barriers that make it difficult to reach the objective?

One of the main barriers is the cost of some equipment and building improvements. However, in some cases there might also be problems with the country/city infrastructure: if water or electricity supply is not sufficient or with low quality, it can become a major barrier to run a laboratory.

- Criteria for success evaluation?

A laboratory can consider that investment in equipment and infrastructure to be successful if it has an impact on precision or accuracy of its results, if this new equipment/infrastructure is necessary to get a certification or an accreditation, or if it helps improving the safety or working conditions of the staff members.

4.3 Staff qualification and performance

The staff is the most valuable element of a laboratory. Trained (and motivated) staff is an essential ingredient to a successful laboratory, i.e. a laboratory able to deliver good quality results and following all standard procedures during its everyday activities. The best equipment and infrastructure can deliver good quality results only if trained staff members and qualified managers are able to correctly run such equipment and correctly collect and interpret their results.

To run a laboratory and obtain good results, not only is a sufficient number of staff necessary, but this staff also needs to have appropriate qualifications and get trainings to be sure that all laboratory operations are correctly executed, under an adequate laboratory manager supervision. While a high budget can help to get expensive instruments, much more than funds are necessary to get qualified staff and laboratory managers.

Our survey collected some basics information about the staff qualification and performance (see Section 3, question 11 to 16) that will now be examined to provide some recommendations for GLOSOLAN to consider when defining its roadmap.

- What needs to be improved?

In many laboratories the survey has highlighted (i) a high number of temporary staff and (ii) a lack of education and specific trainings for soil samples and (iii) a lack of regular trainings even for permanent staff.

The current situation could be improved by organising initial or regular trainings on general qualification firstly for chemical analyses work.

Secondly, there should be trainings especially concerning soil analysis (i.e. that even people having experience for chemistry should learn): soil sample handling and preparation, calibration and running of analytical instruments used for soils (texture for example), presenting and explaining the specific SOP for each soil parameter, reporting the results with correct and standard units for soil science and agronomy, assess and solve some elementary daily problems concerning soil samples.
Training should also concern the good laboratory practices, in particular: using maintenance logbook, reporting the troubles on written documents, reviewing the results of the internal control samples, running the analysis for the external proficiency testing samples, being able to understand the safety rules, etc.

- At what level can the decision be made?

Countries have to make staff trainings mandatory to get an accreditation; the laboratory managers can decide to test the competence of the staff, and organise regular trainings to improve or maintain these competences.

GLOSOLAN in agreement with RESOLANs can provide a type of manual presenting the knowledge and skills that soil laboratory staff should have by: (i) developing training programmes concerning the different aspects of soil analysis laboratories , (ii) suggest what should be the minimal level of skills and competency for different aspects of soil analysis laboratories and then develop the tests that the staff has to pass.

- What is an achievable objective?

GLOSOLAN should make freely available videos, e-books etc. for all categories of soil laboratory staff members.

Each laboratory should organise initial trainings for new staff, and annually test the performance with the support from GLOSOLAN recommendations.

- Drivers/facilitators to reach the objective?

If the most advanced laboratories act as volunteers to organise trainings, it would be much easier for less advanced labs to reach the above objectives.

It will also be necessary to identify who will cover the cost associated with such trainings (traveling, accommodation, etc…) as well as the production of manuals and video.

- Barriers that make it difficult to reach the objective?

Because of the differences in languages, it is recommended to develop e-books and videos and to organise trainings that can be understood by laboratory staff from all countries.

- Criteria for success evaluation?

Success can be estimated using:
- the e-books and videos that were downloaded,
- number of qualified laboratories that are volunteer to train the other lab or host the trainings,
- number of staff that participate to the trainings,
- number of staff that can pass the competency test,
- Number of countries that make the initial training and competency test mandatory for the soil analysis laboratories,
- number of countries and regions where staff has been trained.

(Note that even laboratories that do not use standard operating procedures should have trained staff and can join the RESOLANs and GLOSOLAN to get a support on these aspects).

4.4 Internal quality control

One of the objectives of GLOSOLAN is to standardise the analytical procedures in soil laboratories around the world, so that all the laboratories can provide similar results when receiving the same soil sample. To reach this objective, it is primarily necessary to be sure that the same sample analysed several times in the same laboratory would provide the same result within a defined range (i.e. the uncertainty). This can be controlled by the laboratory itself if it runs internal quality control. Our survey also provided some information on these aspects (see Section 9, questions 59 to 65).

What needs to be improved?

The use of internal control samples is already very high, at 85 % of the responding laboratories, but in one third of the laboratories, these quality controls are used only once a week or less frequently to track the performance of the laboratory.

Consequently it seems necessary to increase the frequency at which the results are used to track the performances.

No question was asked about the way these data are recorded and used and shown to the customers for quality assurance purposes. This aspect should be considered in the future for improving the performance of the laboratory and fulfil need of customers to be sure to get good quality results.

At what level can the decision be made?

The laboratory managers have to take action to implement internal quality control at a regular basis. For each analytical parameter, GLOSOLAN and RESOLANs should provide clear recommendations on the best procedures of internal control, in agreement with the general rules of good laboratory practices.

What is an achievable objective?

Each laboratory should prepare a stock of at least two or three soils with different characteristics. This samples would be used at least daily in routine laboratories (or in each batch for research laboratories) in order to track the quality of the results. The data of control samples should be recorded in a local database, quality charts plotted and quality of the laboratory calculated for each parameters.

Drivers/facilitators to reach the objective?

Each institute should allocate budget to the collection, preparation and storage of these two or three soil samples that must be used as internal control samples.

A platform for discussion between laboratory managers to exchange information on how to organise the internal quality control and how to solve the problems they detected should be established.

Barriers that make it difficult to reach the objective?

The highest barrier will be the human tendency to keep the same habits and be reluctant to analyse samples that are considered as additional work or considered as useless or simply a waste of time. The cost of additional analysis and the time spent to analyses them that will reduce budget and time dedicated to client's samples.

Criteria for success evaluation?

Capability of the laboratories to provide quality charts for the different analysis done by the laboratory.

(Note that even laboratories that do not use the SOPs recommend by GLOSOLAN have to implement IQC and can thus join the RESOLANs and GLOSOLAN to get a support and recommendations on IQC implementation).

4.5 External quality assessment (EQA)

When IQC helps to evaluate and improve the precision of a laboratory (whatever the parameters analysed and the procedure that is used), the external quality assessment (EQA) helps to evaluate the accuracy of the results, this is the closeness to the 'true' or 'consensus' value. In order to make soil data comparable and exchangeable worldwide, sound and harmonized data should be produced. These could thereafter be used for monitoring, reporting and mapping activities as well as in decision-making. Participation to EQA was examined in our survey (see Section 10, question 66 to 69).

What needs to be improved?

A large majority (81%) of the laboratories are already involved in external quality control and would probably be ready to participate to a global proficiency test (PT) or ring test.

It is possible (i) to increase participation within a ring test by involving as many of the remaining laboratories as possible and (ii) to provide the same material to all the laboratories interested in joining a global ring test.

At what level can the decision be made?

The GLOSOLAN and the RESOLANs should organise regional and global ring tests.

What is an achievable objective?

To get at least the reference laboratory of each country be involved in such ring tests and also to get the research laboratories and routine laboratories having international connections.

Drivers/facilitators to reach the objective?

Financial support to collect, prepare and send the samples in the different laboratories.
Volunteer expert for statistical analysis to interpret the results and write a report.

Barriers that make it difficult to reach the objective?

Due to custom regulations, it currently seems very difficult to send soil samples in some countries and make a ring test that is really international; as a first step it would be possible to organise ring test at the level of the RESOLANs that would include as much countries as possible (because custom problems exist even at this level).

Criteria for success evaluation?

The number of participating regions, reference laboratories, number of countries, number of laboratories, global or regional improvement of laboratory accuracy.
(Note that laboratories that do not use the GLOSOLAN's SOPs should be motivated to joint the GLOSOLAN and RESOLANs ring test to facilitate the harmonisation of analytical results received from all laboratories and countries).

4.6 Certification/accreditation

Certification represents a written assurance by a third party of the conformity of a product, process or service to specified requirements. Accreditation is the formal recognition by an authoritative body of competence to work to specified standards. Both accreditation and certification prove that a laboratory provides accurate and reliable results.

The difference is that each country can host multiple certification bodies (ISO is the most famous one) but each country has only one recognized national accreditation (ministries, special institutions, etc.)

What needs to be improved?

Half of the laboratory respondents did not get certification or accreditation. This number should be reduced.

At what level can the decision be made?

GLOSOLAN should set up its own certificate and laboratory mangers could decide to join the certification process.

What is an achievable objective?

To launch a GLOSOLAN certificate of quality for soil analysis results.

Drivers/facilitators to reach the objective?

Experts ready to contribute in setting up such a certificate, and willing to join the audit and evaluation of the laboratories.

Barriers that make it difficult to reach the objective?

Budget availability to cover the cost of organising discussion meetings to set up the certificate.
Labour time to develop such a system and to organise the audit.
Competent expert in this field are rare.

Criteria for success evaluation?

The number of laboratories that get the certificate, the number of countries and institutions that request GLOSOLAN certificate for soil analysis laboratories.

____

5 Conclusions

Recommended actions for GLOSOLAN – Towards the GLOSOLAN Roadmap for 2019

- To stimulate the development of standard operating procedures (SOPs), GLOSOLAN should propose draft SOPs for a specified set of the most common/important soil parameters. At present, the operational procedures are so diverse, that it would be difficult to implement a single SOP for each parameter that would be adopted by soil laboratories world-wide; consequently it seems necessary to first identify what operational procedures are most likely to impact results obtained for a particular soil parameter, and then decide how an SOP can be designed to accommodate regional/local practices. This should be addressed during the second GLOSOLAN meeting .
- To improve staff qualifications, GLOSOLAN should develop e-books and videos to disseminate knowledge concerning good laboratory practices (GLPs) and provide information on specific aspects related to soil analysis. GLOSOLAN should also propose a training programme to increase staff competence that could be adopted at regional scale and updated on a regular basis.
- To facilitate the dissemination of such e.books and videos and the adoption of training programmes, it is suggested to stimulate the development of RESOLANs that do not yet exist.
- GLOSOLAN should motivate laboratories to implement internal quality control more frequently by using their internal control soils. By increasing the number of internal quality control analyses, laboratories can better assess, monitor and benchmark their precision and also detect systemic problems that need to be solved.
- GLOSOLAN should organise a proficiency-testing program or ring test to benchmark the results of each method across laboratories. **Organize ring tests on a regular basis could be done at two levels: regional level and global level** to: 1) evaluate and monitor the performance of existing laboratories (accredited or not); 2) validate standard methods; and 3) set-up new laboratories and train staff.
- GLOSOLAN should establish one or two soil reference laboratories in each region to provide and deliver the necessary technical advice, training program and capacity building.
- GLOSOLAN should set up a communication platform to share information and experience among laboratories. This platform could host a data base to gather, collect and review available literature (FAO/WEPAL/IPNI/IPPI/OECD).
- GLOSOLOAN should develop and promote a certified soil laboratory quality assurance system and provide a GLOSOLOAN accreditation scheme.

Annex 1 First GLOSOLAN Survey

Briefly describe how the survey is organized (mention the sections)

First block of questions were on general information to identify the responding laboratory like

1. Email address * ____
2. Your name * ____
3. Official soil laboratory name * ____
4. Soil laboratory short name or acronym ____
5. Full address of the soil laboratory* ____
6. Country of the soil laboratory * ____
7. Head of the soil laboratory - last name, name____
8. Head of the soil laboratory - e-mail ____

The analysis showed that respondents were …regions

A question (question 9) was asked to know if the lab belonged to any network (this information is useful too identify potential collaboration hubs with existing networks), results for this question are herewith reported:

[You can keep question 9 and 9a as in the survey]
Results for question 9 and 9a

10. Does your laboratory collect national data on agricultural or forest soils?
Single answer
- o Yes, on agricultural soils
- o Yes, on forest soils
- o Yes, on agricultural and forest soils
- o No

GLOBAL AND REGIONAL OVERVIEW (WITH THE GRAPHS)

Staff of the soil laboratory
11. Number of employees with a permanent contract _______
12. Number of employees with a temporary contract _______
13. Percentage of employees who received a formal education on analytical work
Mark only one oval. 0 1 2 3 4 5 6 7 8 9 10 0 % 100%
14. Percentage of employees who were trained to perform analytical work
Mark only one oval. 0 1 2 3 4 5 6 7 8 9 10 0% 100%
15. Percentage of employees who were educated, trained or having experience in "SOIL" analyses
Mark only one oval. 0 1 2 3 4 5 6 7 8 9 10 0% 100%
16. Does your lab have a training program to regularly improve the skills of the employees?
- o Yes
- o No

Infrastructure of the soil laboratory

17. Do you have a sample reception area?
- o Yes
- o No

-

-

18. Do you have a cold room (constant temperature of 4 ° C) to store samples?

-

- o Yes
- o No

18a. If no, please specify where you store samples and the approximate temperature of the storing place

-

19. How do you store samples?
    - o sealed glass
    - o plastic containers
    - o other, please specify

-

20. Do you store the dried, sieved soil samples
    - o at room temperature.
    - o in a dark room

20a. Please specify the temperature of the room.

21. Does the soil laboratory have one or more rooms that are dedicated to the storag of reagents, are the latter organized by groups (acids, bases, flammable, highly toxic compounds and compressed gases) and are these sections labeled accordingly and properly?
- o Yes
- o No

22. Do all chemicals/reagents have labels indicating the receipt, and the opening/disposal dates?
- o Yes
- o No

-

23. Does the soil laboratory have a system to check the receipt and opening dates of chemicals/reagents?
- o Yes
- o No

24. Are the temperature and humidity monitored and recorded **in the sensitive areas (balance room, analytical room)** of soil laboratory?
Single answer
- o Hourly
- o Daily
- o Not regularly
- o Never
- o Other (please specify)

25. Does the soil laboratory have a room dedicated to the preparation of soil samples?
- o Yes
- o No

26. Does the soil laboratory have an analytical room dedicated to the storage and use of balances?
- o Yes
- o No

27. Does the soil laboratory have **a specific area** dedicated to glassware cleaning?
- o Yes
- o No

28. What is the quality of the water used in the soil laboratory?
- o De-ionized water
- o Distilled water
- o Double distilled water
- o Other (please specify)

-

28a. Please specify the resistivity or electrical conductivity of the water used:_______________

29. How often is the EC of the de-ionised/distilled water tested?
- o Hourly
- o Daily

- Not regularly
- Never
- Other (please specify)

Clients of the soil laboratory
Which institutions or organisms send their samples to your laboratory for analysis?

30. Who are the main clients of the soil laboratory? [Tick all that apply]
    - Government departments
    - Research institutions [e.g., universities, governmental research centers]
    - NGOs
    - Fertiliser companies
    - Land users (farmers)
    - Other, please specify ____________________

31. Do the clients request advice on which soil tests to use?
    - Yes
    - No

32. How are results reported to the clients?
    - Hard copy
    - Electronically
    - Both
    - Other (please specify)

33. Who signs the result reports? _________________________________

34. Does the soil laboratory provide an interpretation of the analyses?
    - Yes
    - No
    - Upon request of the client

Analyses performed by the laboratory

35. Which type of soil analyses does your laboratory provide?
    - Tick all that applySoil chemistry
    - Soil physics

- Soil biology
- Other (please specify)

36. Does the laboratory perform analyses that are useful for soil classification?
   - Yes
   - No

36a. If you choose "Yes", please answer the average number per year.____

37. Does the laboratory perform analyses useful for fertilizerrecommendations?
   - Yes
   - No

37a. If you choose "Yes", please answer the average number per year.

38. Specify the analyses performed in the next table.
In column **USE**:
1=For soil classification or national inventory;
2=For fertilizer recommendation

	YES/ NO	# SAMPLES PER YEAR (on average	GENERAL PROCEDURE / METHOD (please describe)	Is the method STANDARD, e.g. ISO? (Yes/no, please specify)	Please specify what this data is USED for	Is the method used ACCREDITATED/CERTIFIED? (please provide details)
pH in H_2O						
pH in KCl						
pH in $CaCl_2$						
Other pH						
Electrical conductivity (EC)						
Total Carbon						
Organic Carbon						

Inorganic Carbon (CO_3)						
Organic Matter						
Dissolved Organic Matter						
Particulated Organic Matter						
Total Nitrogen						
N-NO3 and N-NH4						
Available P by Olsen						
Available P by Bray and Kurtz						
Available P by other method						
CEC in NH_4O-Ac						
CEC by other methods						
Exchangeable K in NH_4O-Ac						
Exchangeable K by other methods						
Exchangeable Ca in NH_4O-Ac						
Exchangeable Ca by other methods						
Exchangeable Mg in NH_4O-Ac						
Exchangeable Mg by other methods						

Exchangeable Na in NH_4O-Ac						
Exchangeable Na by other methods						
Exchangeable acidity						
Al						
Micro elements						
Trace elements						
Al-Fe in Oxalate						
Texture analysis						
Water Retention Curve						
- Dry bulk density						
- Hydraulic conductivity						
- Microbial biomass						
Other microbiology analysis						
Other, please specify						
Other, please specify						
Other, please specify						

39. Do you follow a standard in soil pretreatment?
    - ISO 11464
    - None
    - Other, please specify

40. How do you dry the samples?
    - Air dry
    - Oven dry

- Other, please specify

40a. If you choose “Oven dry”, which temperatura? [No more than]

41. How do you grind the sample?
    - Manual method (e.g. mallet or mortar)
    - Automated method (e.g. mill)
    - Other, please specify

42. What type of sieve do you use?
    - 2 mm sieve
    - 0.5 mm sieve
    - 0.2 mm sieve
    - Other, please specify

pH in water

43. The soil to solution ratio used to determine the pH in water is:
    in mass/volume, please specify____g soil /___mL wáter
    or
    in volume/volumen, please specify ___mL soil/___mL water

44. How long are the samples stirred for (in minutes): _____

45. After stirring, for how long are the samples left to settle (in minutes): _____

46. When measuring the pH, is the electrode submerged in:
    - The clear supernate (clear liquid after leaving suspension unstirred and soil has settled at the bottom)
    - The soil settled at the bottom of the vessel
    - Other, please specify

Carbon

47. Which fraction of the soil is analyzed?
    - Sieved through a 5 mm sieve
    - Sieved through a 0.5 mm sieve
    - Sieved through a 2 mm sieve
    - Other, please specify

48. Specify the soil mass used for the measurements (in g): ____________

49. In case of using the Walkey and Black method, what is the ratio of the potassium permanganate and sulfuric acid?

- 10 : 20
- 10 : 25
- Other, please specify_____

50. For Soil Organic Carbon measurements, are living roots removed from the sample prior to analysis?

- No
- Yes

50a. If you choose "yes", please describe "how" living roots are removed from the sample prior to analysis.

Analytical Procedures

51. Does the soil laboratory have and use any Standard Operating Procedures (SOPs)?
i.e. Standard Operating Procedures are WRITTEN documents that present the details of analytical or administrative procedures)?

- Yes
- No
- Existing but not used

52. Are the analytical SOPs available in the rooms where the analytical tests are conducted?

- Yes
- No

53. In which language are the SOPs written? ______________

54. Does a "Maintenance Log Book" exist for each instrument (balance, spectrometer, etc.)?
A maintenance log book is a record of all the maintenance operations done by the laboratory personnel or by private companies on a given instrument

- Yes
- No

55. Is a “Result Log Book”available near each instrument (balance, spectrometer, etc.)
A result log book is a record of all the results obtained on a given instrument.

- Yes
- No

-

56. How often are the balances in the soil laboratory calibrated?
- Every day
- Every week
- Every month
- Every 3 months
- Every 6 months
- Every year
- Other, please specify

Quality control

57. How many samples do you usually have in an analytical batch?
A batch is a set of samples which are processed/analysed at the same time. _____________

58. Are "blank" samples of the extracting solution included in each analytical batch?*
A blank solution is the solution that contains all extracting reagents, but was not used for any extraction; it is usually used to calibrate instruments and to check for instrument stability during analysis.
- Yes
- No

59. Are "internal control" samples used in the soil laboratory?*
An internal control is a reference soil sample, of known analytical characteristics, available in large quantities (several kilos), and which is analysed in each 'batch' of samples, to check the quality of the results.
- Yes
- No

60. If used, how many internal control samples are used for each analytical batch? ___________

61. Are "quality control samples" used in the soil laboratory?*
- Yes
- No

62. If used, which material is used as "quality control samples"?

Certified Reference Materials (CRMs): A reference material whose property values (purity, concentration, etc.) are established and certified in accordance with metrological principles using established, international best practice protocols. CRMs are used to calibrate the measurement process and they all have common characteristics: 1) Assigned values are accompanied by an uncertainty statement, and 2) Information is given on the methods used to assign values

Internal Reference Material (IRM): A reference material prepared in the respective laboratory to use as an internal control sample for monitoring precision of the lab results in each batch of analysis

Standard Reagent: It can be a certified material if they have certificate that shows the purity, concentration, and traceability

- Certified Reference Material (CRM)
- Internal Reference Material (IRM)
- Standard reagent
- Other, please specify

63. Are the data obtained from internal control used to track the soil laboratory performance?
   - Yes, performance is tracked every day
   - Yes, performance is tracked every week
   - Yes, performance is tracked every month
   - Yes, performance is tracked every 3 months
   - Yes, performance is tracked every 6 months
   - Yes, performance is tracked every year
   - No
   - Other, please specify

64. What are the acceptance limits used to consider the analysis of an "internal control sample" or "quality control sample" reproducible?
   - 5%
   - 10%
   - 15%
   - Other, please specify

65. When results from "internal control samples" or "quality control samples" fall out of the acceptance limits:
   - The batch of samples is reanalyzed
   - The analytical data near the control are reanalyzed
   - The analytical data is corrected
   - No consequence is drawn

Soil laboratory certification

66. Does the soil laboratory participate in proficiency tests or inter-laboratory comparisons?*Proficiency testing or inter-laboratory comparison compares the measured results

obtained by different laboratories. Hereby, soil samples are sent to different laboratories. The results reported by each laboratory are compared to a reference value.

- Yes
- No

67. If yes, at which level does the proficiency test / inter-laboratory comparison occur?

- National
- International
- Other, please specify

68. If applicable, how often does the soil laboratory participate in proficiency tests / inter-laboratory comparisons?

- Once every 2-5 years
- 1 time per year
- 2-4 times per year
- Over 5 times per year
- Other, please specify

69. Is the soil laboratory certified?

- Yes, under ISO 17025
- Yes, under ISO 9000
- No
- Other, please specify

70. Do you have a data library?

- Yes
- No

71. General comments.
Please provide any further relevant information or details from the soil laboratory, methods

72. What could other soil laboratories learn from your laboratory?

73. What could your laboratory do to improve?

[Closing remarks]

Thanks for taking the survey.

For more information on the first GLOSOLAN meeting, please visit http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/glosolan/en/

For more information on Pillar 5 of the Global Soil Partnership, please visit http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/en/

For more information on the Global Soil Partnership, please visit http://www.fao.org/global-soil-partnership/about/why-the-partnership/en/

Please address your questions to GSP-Secretariat@fao.org