50x2030 SOIL SESSIONS

STRATEGIZING TO IMPROVE SOIL HEALTH DATA IN AGRICULTURAL SURVEYS

SUMMARY OF MEETINGS
NOVEMBER 2-4, 2021

50x2030
DATA-SMART AGRICULTURE

Session Objectives

In a world with increasing climate change and intensifying food insecurity, agricultural productivity is central to development. Increasing agricultural productivity requires a detailed understanding of cultivated land and its limitations, and how these shortcomings can be addressed. Towards this end, objective soil analyses can reveal objective levels of soil nutrients and crop-specific soil constraints to productivity. Soil monitoring conducted at the plot-level as part of household or farm surveys has the added benefit of integrating data on soil properties with farm management practices, input use, and agricultural outputs, as well as household socio-demographics, allowing for a thorough understanding of the relationships between soil health and key development outcomes. Household and farm surveys, however, often rely on subjective soil health data which have been found in research conducted by the World Agroforestry Centre (ICRAF) and the Living Standards Measurement Study (LSMS) to be poor predictors of objective measurements of soil attributes and are subsequently limited in their ability to accurately identify soil constraints and their productivity implications. The Methods & Tools Development component of the 50x2030 Initiative, which aims to identify, validate, and support the scale up of improved methods of data collection in household and agricultural survey operations, has prioritized a line of research specifically to tackle these critical gaps in high quality, high resolution soil data integrated with household and farm surveys.

This set of meetings brought together, by invitation, stakeholders with various data needs, tool development, and research and/or policy aims to discuss the state of currently available soil health data and innovative technologies that have the potential to transform the way soil data is collected in surveys, as well as data collected on soil management practices. The identification of user-specific data gaps and the burgeoning data demands of microeconomists, geospatial analysts, and policy makers, and discussion around potential means to address unmet data needs, will shape the 50x2030 soil research agenda.

The expected outcomes of the workshop were:

(i) agreement on priority research questions on soil health monitoring and innovations, and
(ii) recommendations for the design of a series of methodological experiments to be conducted under the 50x2030 Methods component, resulting in scalable solutions for soil health monitoring under the 50x2030 Initiative and beyond.

The sessions also served to establish a network of experts 50x2030 can continue to interact with to advance the soil health measurement and monitoring agenda.

Summary Report

The agenda of each of the three sessions is provided below, followed by a summary of the day's presentations and discussion.

Nov. 2nd -- Setting the stage – recent directions, lingering gaps, research priorities

Topic	Lead	Duration
Introduction	Gero Carletto (Session Moderator, World Bank)	10 mins
Presentation of the 50x2030 Initiative and research objectives and WB research on soil to date	Sydney Gourlay (World Bank)	20 mins
Sustainable agriculture data: What's missing, what can be improved, and what needs validation?	Rattan Lal (OSU)	20 mins
Q&A on session objectives	All	15 mins
Soil mapping at scale: benefits, limitations, and experience from India	Balwinder Singh (CIMMYT)	15 mins
Linking soil and nutrition: MAPS Project	Edward Joy (LSHTM) / Louise Ander (BGS)	15 mins
Role of soil data in agricultural policy: an economist's perspective	Leah Bevis (OSU)	15 mins
Guided discussion	All	40 mins

In this first session, the objectives were to (i) relay the objectives of the 50x2030 research agenda, with emphasis on household and farm surveys, scalability, and data integration, (ii) identify key data uses and gaps with respect to soil heath and soil management practices, and (iii) start prioritizing the data gaps and key facets of soil data to tackle within the framework of 50x2030.

Gero Carletto opened the session by explaining the ultimate goal of the 50x2030 Initiative's research on the measurement of soil health, which will be informed by the discussions taking place in the Soil Sessions: to identify how soil data can be collected as part of household and farm surveys in a scalable, systematic way. We want to do that for at least a couple of reasons, in addition to the analytical value of having high quality soil data integrated with data on agricultural production: (i) multitopic household surveys have the ability to link agronomic and environmental data with socio-economic data (also providing insights on behavioral effects, wealth and distributional effects, etc.), and (ii) through integration, household and farm surveys can be used as a ground-truthing vehicle to validate other sources of soil data. Evolving technologies create the opportunity to measure soil health in a household/farm survey context, to potentially to measure it at scale, but still there are many unanswered questions on the priority metrics, the appropriate method(s), and the scalability of the available approaches.

Sydney Gourlay presented the objectives and preliminary proposal of the research to be conducted under the 50x2030 Initiative, putting them in the context of the methodological work conducted by the LSMS in collaboration with ICRAF, and research conducted by other groups. After providing a brief background on the 50x2030 Initiative, including its Methods & Tools Development component and its linkages with the Data Production component, she highlighted the work that has been done to date by the LSMS-ISA in collaboration with ICRAF. This work included three methodological studies (in Ethiopia and Uganda) that tested lab-based spectral analysis and subjective farmer assessment against the gold-standard wet chemistry approach (two studies tested lab-based spectral analysis, one tested in-situ spectral analysis). The experience of the previous methodological studies illustrated the need for objective soil measurement, but also the need for a more scalable tool.

The initial strategy for the methodological research program was laid out, for participants to keep in mind and to react to throughout the sessions. This initial strategy was to conduct 2-3 methodological studies in different contexts, each of which would:

i. allow for direct comparison of in-situ objective measurement (via sensors, apps, and/or photo-based technologies) and a refined set of subjective questions, against gold-standard (lab-based) measures
ii. collect soil data at the plot-level
iii. piggyback related methodological research, including climate & weather and potentially fertilizer quality
iv. explore the potential for developing a protocol for smart sub-sampling of soil data (to allow interpolation to the sample at large)
v. assess complementarity/substitutability of currently available geospatial data on soils

Following the introductory presentation by Sydney, in which the context, background, and objectives were described, **Dr. Rattan Lal** gave an inspired presentation on the state of data on sustainable agriculture. He noted that despite the fact that soil is not mentioned in any of the 17 SDGs explicitly, it is linked with numerous development outcomes and we cannot afford to ignore it. More (and more granular) data is needed, especially in the areas of soil degradation, soil salinity, and soil carbon sequestration, to name a few priority areas. He highlighted key open questions that are critical for sustainable agricultural and climate change, including the permanence (or lack thereof) of carbon sequestration, and the appropriate pricing for carbon farming. There are many unknowns in the field, such as the appropriate means of converting SOC to SOM, and the actual increase in agricultural productivity for a given change in SOC where data is lacking at a granular level. Dr. Lal also cautioned against the use of modelling as a replacement for real data, and reiterated the importance of the quantity, quality, and context-specificity of the ground data informing such models. In the Q&A following the presentation, Dr. Lal suggested that the collection of soil data in these types of surveys could serve as a baseline measure, ideally with measurements repeated every 5 years at the same precise locations and with a consistent methodology. He also indicated that 50cm depth was recommended in most cases.

In the second half of the session, we heard from three different types of data users and producers. First, **Balwinder Singh** discussed soil mapping, based on his experience with CIMMYT in India. This presentation was strongly related to the discussions in the chat around the reliability, resolution, and quantity/quality of underlying ground data in soil mapping more generally. Based on the discussions, it was clear the answers to these questions are heavily context specific, with some soil mapping products utilizing a large

number of ground-based data points (such as that presented by Balwinder) and others with insufficient (context specific) ground data or with insufficient temporal resolution. Given the number of samples underlying the soil map in India, Balwinder presented an interesting exercise in which they tested the necessity of such a large sample size, by randomly selecting 10% of their samples and replicating the mapping exercise. The mapping with 10% was very similar to that using the full sample.

While the primary use of soil data to the 50x2030 Initiative is related to its role in agricultural productivity, **Louise Ander** presented an additional data use – linking soil health and human nutritional outcomes, specifically through the MAPS and GeoNutrition projects. Under the MAPS project, a web-hosted tool is developed to enable the estimates of micronutrient deficiencies to be communicated at national and sub-national scales in Africa, linking food consumption and human nutrient levels. The GeoNutrition project also targets human micronutrient deficiencies, by bringing together data on soil, agriculture and landscapes to understand the factors affecting the supply of micronutrients to crops and food systems. **Leah Bevis** echoed the potential insights from linking soils and nutrition in her presentation on the role of soil data in agricultural policy, along with enumerating a variety of other questions that could be addressed with high-resolution soil data (and the related constraints). Those questions included those relevant to agricultural productivity (how much productivity is lost due to poor soil fertility and, separately, trace nutrient deficiency?; how localized do soil-based fertilizer recommendations need to be?; how are farmer input decisions and perceptions shaped by and aligned with objective measurements?) and inequality (how does poor land productivity contribute to spatial patterns of poverty?; is there a "resource curse" on high-quality land?). Some of the most notable constraints mentioned by Leah include the fact that spatial variability varies by soil characteristic and also by geographic location (likely limiting the appropriateness of a one-size-fits-all protocol), and the issues associated with measuring soil characteristics over time, based on measurement error both within and across methods.

Participants were very active in the chat, where conversations were held both related to the presentations above and on parallel topics. One of the topics that garnered much attention, and is related to the discussions on Day 2 of the Soil Sessions, was that of the various spectral sensors now available for in-situ measurement and key considerations for their use (more on this in Day 2 summary).

The session highlighted that the parameters for soil data are dependent on the associated use case, of which there are many. Gero, session moderator, noted in his concluding remarks our aim to find a common denominator in terms of the key soil metrics to be measured, as well as their spatial and temporal resolution. We won't be able to meet all of the data needs for each group of users, to meet all objectives, but we can maximize the utility of soil data to the user base at large, while also meeting the needs of the 50x2030 Initiative's objectives.

Nov. 3rd -- Tackling Gaps in Measuring Soil Health – Approaches & Tools

Topic	Lead	Duration
Introduction	Natalia Rodriguez Eugenio (Session Moderator, FAO)	10 mins

Soil spectrometry: what it tells us, what is doesn't, and experience at ICRAF (lab and in-situ)	Ermias Betemariam (ICRAF)	15 mins
Developments in leveraging soil information for digital farm advisory	Keith Shepherd (iSDA Africa)	15 mins
Q & A and Discussion	-	*20 mins*
Global Soil Doctors Programme: Experience from FAO	Carolina Olivera Sanchez (FAO)	15 mins
App-based options for estimating soil health: LandPKS	Jeff Herrick (LandPKS)	15 mins
Guided discussion	All	60 mins

The second session drilled down into discussion of potential avenues for addressing the data gaps identified in the first session, with a focus on technological solutions. We discussed the value, advantages and challenges of in-field spectroscopy, application-based approaches like LandPKS, alternative in-field sensors, and integration of ground-based and geospatial data, and the ways in which these approaches could be used, either alone or in combination, to address data gaps. The intended outcome of the session as a clear understanding of the tools available, and the types of tools to be targeted for future research, as well as their advantages and disadvantages with respect to implementation in conjunction with household surveys.

Ermias Betemariam kicked off the presentations with his discussion of soil spectrometry, bringing in his experience working with the LSMS team on previous methodological work. He highlighted the ability of spectroscopy to analyze soils as well as other materials such as plants, fertilizers, etc., all with a relative high throughput and low cost vis-à-vis traditional wet chemistry methods. To provide support to the use of spectral testing, which relies on calibration models, Ermias presented the accuracy of mid-infrared (MIR) predictions for multiple soil properties (all with R^2 of at least 0.94). He also noted ICRAFs large and growing library of soil samples from the African continent which can be utilized for such calibration (over 150,000 samples currently). Finally, Ermias described the previous methodological work on soil measurement in household surveys done in collaboration with the LSMS, which ultimately illustrated the analytical value of objectively measured soil data in household surveys while also highlighting the need for more scalable in-situ tools. Spectrometry holds promise, however, as regional capacities are increasing, as is the availability of ground-based samples to calibrate predictive models.

Keith Shepherd continued the discussion on the use of spectral soil analysis with his presentation on iSDA Africa and its use of spectrometry in its digital farm advisory service. He illustrated the farm level digital soil map for Africa, iSDAsoil 30m resolution, generated from the analysis of over 100,000 samples (with prediction uncertainty made available). iSDA's advisory services utilize this map along with other covariates, in a Bayesian network, to advise extension agents and farmers on nutrient management and yield expectations. Keith also discussed the question of 'what is a good level of soil organic matter?", a question that arose also in the first day of the session, putting forth a simple soil health index based on the ratio of organic carbon to clay, with thresholds for very good to degraded soils, as well as other approaches using more soil properties and the global estimation service.[1]

[1] Prout, J.M., Shepherd, K.D. McGrath, S.P., Kirk, G.J.D., Haefele, S.M. (2020). What is a good level of soil organic matter? An index based on organic carbon to clay ratio. *European Journal of Soil Science* 2020:1-11

In the second half of the session, we turned away from spectrometry and focused on alternative approaches and programs. **Carolina Olivera Sanchez** presented the work of **t**he FAO's Global Soils Partnership and Soil Doctors program, including the development of the *Voluntary Guidelines for Sustainable Soil Management* and the *Protocol for the Assessment of Sustainable Soil Management*. In the latter, the recommended set of indicators includes soil productivity, soil organic carbon, soil physical properties (bulk density and AWC), and soil biological activity (respiration rate). Carolina describes the Global Soil Doctors Programme, a farmer-to-farmer training program to support capacity building of farmers and extension services. Through this program, a number of guidance materials were developed, including a manual for soil testing based on observation the use of a testing kit.

Jeff Herrick presented an app-based approach to estimating soil health –LandPKS. LandPKS utilizes site-based soil data in conjunction with soil maps to localize predictions. Jeff provided the example of the use of LandPKS data to measure maize soil suitability, against maize sol suitability measured by publicly available sol maps, which illustrated the greater variation in suitability exhibited with the use of LandPKS data (a finding in line with ongoing 50x2030 research on using plot-level soil analysis to measure maize soil suitability vis-à-vis geospatial products). Jeff and his team aim to minimize field observations and measurements by applying *value of information* analysis. Jeff made the important distinction between management-relevant soil properties (such as texture, depth, nutrient availability) and management-responsive soil properties (such as soil organic matter and soil structure), their static vs dynamic nature, and the need to consider these against data use objectives. He also highlighted the need to think about when soil variability does and does not matter – something to be considered in the design of the methodological studies.

Numerous in-field spectrometers were put forth, with questions and caution about their reliability and calibration to the contexts of interest, in both the chat and discussion. Tom Hengl shared several in-situ sensor options, including FarmLab, Yardstick, the Agilent 4300 Handheld FTIR, and others (see page 10 for full list). While the need to be cautious with the use of spectrometers when using calibration models from contexts different from that in which you are working, it was evident that there are a growing number of global spectral libraries that could be utilized for calibration going forward.

There was also much discussion on the selection of soil samples, including the depth necessary, number of samples, and the possibility of a dynamic sample selection (and metric selection) protocol based on plot characteristics. With respect to depth, both Rattan Lal and Keith Shepherd suggested 50cm depth. The outstanding question, however, is whether it is necessary to analyze separately top- and sub-soil samples (as done in previous LSMS methods research), or if a single sample to 50cm depth is sufficient (and should that be 0-50cm or 20-50cm).

An additional strand of discussion was on farmer perceptions of soil health and their knowledge of soil needs (e.g., if they had objective soil data would they know how to interpret it for their given crops). Hope Michelson shared her experiences in Tanzania and Malawi on farmers' behavioral change as a result of receiving objective soil analysis results, as well as a study on the willingness to pay for such information.

At the end of the session, Sydney asked participants to indicate in the chat the top three soil metrics they would prioritize, for their own respective objectives. There was overwhelming support for prioritization of pH, SOC, and texture (admittedly with a sample of 9, but no voices against this prioritization in the larger group).

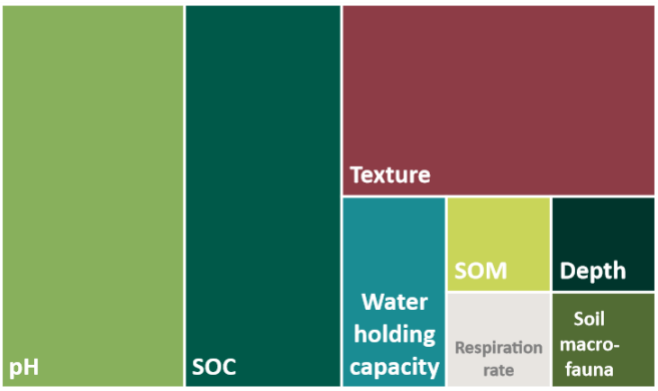

Figure 1. Small-scale poll on top 3 soil metrics to prioritize (N=9)

Nov. 4th -- Soil Management Practices & Sustainable Agriculture

Topic	Lead	Duration
Introduction	Alberto Zezza (Session Moderator, World Bank)	10 mins
Measuring what matters in sustainable agriculture: Opportunities and challenges	Romina Cavatassi (IFAD)	15 mins
Current coverage in 50x2030 instruments	Adriana Paolantonio (World Bank)	15 mins
Monitoring changes in soil carbon: Data needs and methods	Nkulumo Zinyengere (World Bank)	15 mins
Interactive Panel Discussion: Strategizing for Methodological Experiments & Scalable Solutions	Panelists: Jeff Herrick (LandPKS); Leigh Winowiecki (ICRAF); Julian Lampietti (World Bank); Ronald Vargas (FAO); Leah Bevis (OSU)	55 mins
Session conclusions & next steps	Sydney Gourlay (World Bank)	10 mins

In the third and final session we, for the first half, shifted the focus from measurement of soil health itself to data needs and gaps on soil management and sustainable agriculture practices. The second half of the session was devoted to an interactive panel discussion, bringing together the discussions of the week to strategize on the methodological experiments to be conducted by the 50x2030 Initiative and the potential scalable solutions to stem from those studies.

Romina Cavatassi opened up the day with her presentation on measuring what matters in sustainable agriculture. She highlighted IFAD's work on measuring adaptation, which is key to ensuring sustainability, through the Adaptation for Smallholder Agriculture Programme. Some of the sustainable agriculture practices noted include agroforestry, the use of biogas, and the use of efficient irrigation systems. In IFADs impact evaluations on sustainable agriculture and adaptation they collect, generally, data on land

preparation, soil fertility, irrigation, soil conservation, and agroforestry, among others. Romina also illustration the Climate Adaptation in Rural Development (CARD) tool, an ensemble of global gridded crop-climate models in order to explore a number of possible levels of risk in the same warming scenario, for 17 major crops. She emphasized the absence of data on adaptation and sustainable agriculture on a broad scale.

Following Romina's presentation, **Adriana Paolantonio** presented a summary of the current coverage of questions related to sustainable agriculture practices and soil in the 50x2030 questionnaire instruments. Adriana's presentation clarified the 50x2030 context and questionnaire design for many participants as she provided an overview of the Initiative's questionnaire structure and questions that are complementary to objectively measured soil health. Key domains of relevant questions include soil health, irrigation, agricultural input use, and agricultural practices, all of which are integrated with additional socio-economic data from the households/farms.

The final presentation of the session, by **Nkulumo Zinyengere**, focused on the importance and measurement of soil carbon and monitoring, reporting, and verification (MRV) systems. He argued that accounting for changes in soil organic carbon stocks is key to foster investment in sustainable agricultural practices. Through various engagements with experts, Nkulumo and his team have developed the Soil Organic Carbon MRV Sourcebook and are looking to pilot MRVs in various contexts.

Following the presentations, **Alberto Zezza**, moderator of the session, led an interactive panel discussion with Jeff Herrick, Leah Bevis, Leigh Winowiecki, Ronald Vargas, and Julian Lampietti. Prior to jumping into the discussion, Alberto reiterated that through the course of the sessions we had converged on some priority metrics (pH, SOC, and texture), but not necessarily how to best measure them. Keeping that in mind, as well as the context and data collection mechanism of the 50x2030 Initiative, the panelists addressed a series of questions.

Jeff Herrick, in response to a question on what metrics the Initiative should prioritize and for what particular use value, suggested that we look at model uncertainties and see where we can make improvements to those models with improved ground data. **Leah Bevis**, in response to the same question, suggested that if we are after data to add value to household level analysis, we may not necessarily need household level soil data. Collection of soil data the village level would be a significant improvement over what exists today.

Relatedly, **Leigh Winowiecki** and **Ronald Vargas** spoke on their views of 'low-hanging fruit' in the soil data space. Leigh pointed to the need for quantifiable metrics to detect changes over time, noting also the importance of keeping farmers engaged in this process. Ronald reiterated the need to match data needs with data uses, as the needs will vary. He also cautioned of the variability in measurements across and within labs, particularly in developing country contexts.

In terms of methods for making this type of data collection valuable for operations and improving its sustainability, **Julian Lampietti** suggested that we need to create markets for the data to encourage use of the data by several types of users, including researchers, fertilizer companies, and other private sector actors. He put forth the idea of a survey of data users to identify what data would be most valuable to those users.

Alberto posed the question of what complementary data (i.e., data beyond objective soil measurements) should be prioritized. **Leah Bevis** pointed out the boundaries of the analysis we hope to undertake with this data – noting that for casual inference, extended repeated panels are necessary. Instead, we can conduct descriptive type work like productivity analysis, and linkages between crop choice, productivity and soil health, for example. On the inclusion of subjective farmer perceptions of soil health as complements to objective measures, Leah suggested that the use of these variables be strongly considered (as evidence suggests they are typically poorly correlated with objective measures) before doing so. **Leigh Winowiecki** indicated a need for collection of complementary data on factors that influence soil health and resilience. Relatedly, Leigh also highlighted ICRAFs work on developing and utilizing the Land Degradation Surveillance Framework (LDSF) methodology. Finally, **Jeff Herrick** shared some closing words on what he sees as a critical component for the success and value of this type of data collection effort – the need to directly link the soil, the landscape, and productivity from a given plot, focusing first on the relationship between soil and yields, and then expanding from there as needed.

In parallel to the discussion pane, some important points were raised in the chat. One of the key issues or considerations raised is the issue of measurement error and the feasibility of monitoring change over time. **Hope Michelson** gave an example in which they conducted a panel survey 4 years apart and the soil scientists involved in the project expressed significant concern about the ability to measure changes over time versus measurement differences. This caution was also echoed by **Leah Bevis,** who had a similar experience in a 10-year panel. This is something to be strongly considered in the design and analysis of samples, as very consistent methods (and preferably lab personnel) should be maintained in the case of panel analysis aimed at understanding change over time. One way to gain more confidence in the measures and therefore the change over time would be to do repeated analysis on each to get a sense of within-year error.

Key Takeaways & Next Steps

The Soil Sessions revealed the breadth of uses for soil data, the many data gaps, and the technological opportunities for addressing those gaps. In terms of narrowing down the data needs and gaps that should be prioritized, keeping in mind the broader 50x2030 Initiative objectives and data collection environment, we achieved some consensus on the priority metrics to be measured (pH, soil organic carbon, and texture) though it was consistently noted that the optimal metrics should be determined in light of the analytical objectives. And while we would ideally be able to meet the data needs for all of the various analytical objectives, that will not happen in this type of context. What we aim to measure is the common denominator, the metrics and complementary variables that will enable a wide variety of analysis while also meeting the direct needs of the 50x2030 Initiative (measuring agricultural productivity).

Throughout the sessions we discussed the available technologies, including application-based approaches, soil spectrometry (in lab and in situ), and enumerator-implemented kits and observations. More work is needed in order to identify the methods to be tested, but valuable points were made regarding the need to consider the context of the underlying calibration models (for spectral-based tools) and the value additions that can be made through "low tech" interventions such as enumerator-assessed texture and photo-based color analysis. The measurement error associated with the various methods, and their sensitivity to enumerator/lab effects, also need to be considered if aiming to measure change in properties over time.

In terms of temporal resolution, spatial resolution, and soil sampling procedures, a consensus emerged on: (i) the need to sample to 50cm depth, and (ii) replication of soil analysis approximately every 5 years (though this is to be reviewed based on the properties to be measured). In terms of spatial resolution, there were mixed opinions on the need to have plot-level analysis. While the vast majority agreed that plot-level soil samples would be valuable for the plot/household/farm level analysis, it was also stated by some that community/village level analysis would add significant value to the current data landscape.

The next phase of work will be focused on identifying the tradeoffs of the various tools for measuring the priority metrics (pH, SOC, texture + farmer perception), for each specific use case (e.g., agricultural productivity, sustainable agriculture and climate, nutrition, etc.). The assessment, which will ultimately inform the tools that are most appropriate for inclusion in the methodological validation studies, will review the tradeoffs in terms of: (i) analytical value, (ii) cost, (iii) temporal resolution requirements, and (iv) sample size requirements. Tools with the optimal combination of analytical value, cost-effectiveness, and scalability will be carried forward into the methodological studies of the Initiative. Following this assessment and identification of the tools and approaches to be tested, a concept note with the design of the first methodological study will be developed, likely in combination with other lines of 50x2030 research on climate and non-labor inputs.

The Soil Sessions *started* the discussion with experts and stakeholders on the best way to collect data on soil health in agricultural surveys, it did not *finish* it. Further discussion and collaboration on specific areas will be sought going forward.

Participants

1. Adriana Paolantonio – World Bank (DECPM)
2. Alberto Zezza – World Bank (DECPM)
3. Balwinder Singh – Cropping Systems Simulation Modeler, CIMMYT India
4. Carolina Olivera Sanchez - FAO
5. Casey Maue – Stanford/PSE
6. Edward Joy – London School of Hygiene and Tropical Medicine
7. Ermias Aynekulu Betemariam – Land Health Scientist, ICRAF
8. Flavio Bolliger - FAO
9. Gero Carletto – World Bank (DECPM)
10. Giulia Ponzini – World Bank (DECPM)
11. Hope Michelson – University of Illinois
12. Ichsani Wheeler - OpenGeoHub Foundation
13. James Stevenson – Senior Researcher, CGIAR SPIA
14. Jeff Herrick – LandPKS Global Lead, LandPKS/USDA-ARS
15. John Ilukor – World Bank (DECPM)
16. Jonathan Maynard – Research Analytical Scientist, LandPKS
17. Julian Lampietti – World Bank
18. Keith Shepherd – iSDA Africa
19. Kevin McGee – World Bank (DECPM)
20. Kosmowski, Frederic - CGIAR
21. Leah Bevis - Ohio State University
22. Leigh Winowiecki - Leader, Land Health Decisions, ICRAF
23. Louise Ander – University of Nottingham/British Geological Survey
24. Marco Tiberti – World Bank (DECPM)
25. Marie Agnes Jouanjean – World Bank
26. Natalia Rodriguez Eugenio - FAO
27. Nkulumo Zinyengere – World Bank
28. Parmesh Shah – World Bank
29. Philip Wollburg – World Bank (DECPM)
30. Rattan Lal - Ohio State University
31. Romina Cavatassi - IFAD
32. Ronald Vargas - FAO
33. Sarah A. Simons – World Bank
34. Siobhan Murray – World Bank (DECPM)
35. Sydney Gourlay – World Bank (DECPM)
36. Talip Kilic – World Bank (DECPM)
37. Tom Hengl - OpenGeoHub Foundation
38. William R. Sutton – World Bank
39. Yusuf Yigini – FAO

Resources shared in the chat

Papers:

- Rooting for food security in Sub-Saharan Africa
- Mapping of soil properties and land degradation risk in Africa using MODIS reflectance
- Soil carbon debt of 12,000 years of human land use
- Mapping rootable depth and root zone plant-available water holding capacity of the soil of sub-Saharan Africa
- Better soils for healthier lives? An econometric assessment of the link between soil nutrients and malnutrition in Sub-Saharan Africa
- On the Origins of Gender Roles: Women and the Plough
- Future of the human climate niche
- Evaluation of a miniaturized NIR spectrometer for cultivar identification: The case of barley, chickpea and sorghum in Ethiopia
- African soil properties and nutrients mapped at 30 m spatial resolution using two-scale ensemble machine learning
- A Comparison of Soil Texture-by-Feel Estimates: Implications for the Citizen Soil Scientist
- Collecting the Dirt on Soils : Advancements in Plot-Level Soil Testing and Implications for Agricultural Statistics

Tools & Others:

- LSMS Guidebook -- Spectral Soil Analysis and Household Surveys: A Guidebook for Integration
- Coalition of Action 4 Soil Health (CA4SH)
- Shining a light on soils for land restoration
- Soil and Agronomy Data Cube for Africa at 30-m spatial resolution
- Exploring a Dynamic Soil Information System: Proceedings of a Workshop (2021)
- full tutorial in digital/predictive soil mapping https://soilmapper.org/
- The Land Degradation Surveillance Framework (LDSF) (blog)
- https://soilspectroscopy.org [to receive updates on upcoming Open Soil Spectral Library under this project, register to https://twitter.com/soilspec --> courtesy of Tom Hengl]
- Use of LandPKS data by OpenGeoHub: https://opengeohub.github.io/SoilSamples/datasets.html#landpks-observations
- Protocol for the assessment of Sustainable Soil Management (FAO)
- Global Soil Organic Sequestration Potential: http://54.229.242.119/GloSIS/
- Global Soil Laboratory Assessment (FAO): https://www.fao.org/3/ca7091en/CA7091EN.pdf
- Land Restoration for Achieving the Sustainable Development Goals (report)
- Sensor-based tools:
    - Stenon FarmLab
    - YardStick (https://www.useyardstick.com/),
    - Agilent 4300 Handheld FTIR (https://doi.org/10.3390/s18040993),
    - NeoSpectra NIR Scanner (https://www.si-ware.com/),
    - JDSU MicroNIR (https://doi.org/10.1016/j.geoderma.2018.12.031),
    - LaserAg (https://www.laserag.com/)

Upcoming conferences:

- IUSS Glasgow (https://22wcss.org/conference/abstracts/)
- Living Planet Symposium (https://lps22.esa.int/frontend/index.php)

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