Food and Agriculture Organization of the United Nations

RECSOIL: recarbonization of global soils

Observance of World Day to Combat Desertification and Drought

Wednesday 17 June 2020

GSP Webinars

GLOBAL SOIL PARTNERSHIP

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Introduction

To mark the observance of the World Day to Combat Desertification and Drought 2020, FAO's Global Soil Partnership (GSP), organized a webinar on 17th June 2020 on "RECSOIL: Recarbonization of global soils". This webinar consisted of a combination of three sessions: a high-level opening, keynote presentations, and a panel discussion.

The webinar - moderated by Mr Eduardo Mansur, Director of FAO's Land and Water Division - was attended by 1452 participants from 136 countries and provided a stepping-stone for the implementation of RECSOIL around the world. Many discussions took place in the chat, and overwhelming support was expressed towards the implementation process of RECSOIL in different countries.

Opening Remarks

The high-level opening included FAO Director General Dr Qu Dongyu, the Executive Secretary of the United Nations Convention to Combat Desertification and Drought, Mr Ibrahim Thiaw, and the Costa Rican Minister of Environment and Energy, H.E. Carlos Manuel Rodriguez.

FAO Director-General – Dr Qu Dongyu

Dr Qu Dongyu gave a warm welcome to all the distinguished guests and participants - impressed by the growing number of attendees, he addressed the benefits of a virtual meeting, having the ability to reach more people to celebrate the importance of the World Day to Combat Desertification and Drought, around the world. Dr Dongyu expressed his congratulations to Professor Lal for his recent award of the World Food Prize 2020 and to H.E. Carlos Manuel Rodriguez for his nomination as CEO of GEF. He then noted that desertification is a cancer that is spreading today; there is a need to find a comprehensive solution to tackle the spread of this growing problem. The theme of this year's Desertification and Drought Day is 'food, feed, fiber', the global demand on all three is increasing while land/soil degradation increasing. Dr Dongyu stated that RECSOIL is the initiative that could solve the problem, providing direct support to farmers to encourage best practices and enhance soil organic carbon stocks. Dr Dongyu emphasized the obligation of all organizations, financial institutions, civil societies, and multilateral platforms to support all farmers and provide them with innovative tools and financial incentives to implement best practices by sharing experiences and lessons learned to scale up essential practices.

Dr Dongyu announced FAO's new programme on dry land and water scarcity, which will be presented to the Committee of Agriculture in September as it marked dry land as a necessary part of FAO's work. Research shows that up to 44% of all cultivated systems are in drylands. These areas are home to 30% of the world's population, in more than 100 countries, 90 % of which are developing countries.

Dr Dongyu concluded by referring to the implementation of the new RECSOIL initiative as a positive step towards the UN Decade on Ecosystem Restoration 2021 – 2023 with UNEP. He emphasized that now is the time to prevent and halt land and soil degradation and restore

the degraded ecosystem. He concluded by noting that “Soil is the mother of agriculture, the mother of life".

Executive Secretary, United Nations Convention to Combat Desertification – Mr Ibrahim Thiaw

Mr Ibrahim Thiaw expressed his appreciation to FAO Director General, Dr Dongyu, and GSP for recognizing the observance of the World Day to Combat Desertification and Drought by organizing this important webinar.

Mr Thiaw mentioned that according to IPCC, carbon in its organic form in the soil represents an important part of the solution to climate change, potentially between 25% and 30%. The first meter of soil contains more than twice the amount of carbon contained in the atmosphere and about three times the amount in the world's vegetation. Mr Thiaw mentioned that nowhere else in the biosphere is there greater potential for significant positive change than in our soils. Policies supporting sustainable soil/land management, rehabilitation and restoration of degraded soilsthat focus on maintaining and increasing soil organic carbon also produce an economic, social, and environmental impact far greater than the absolute amount of carbon sequestered. They contribute to soil fertility, which is the foundation of all land based natural and agricultural ecosystems, which provides a major part of the world's food supply, accounting for more than 90% of the calories consumed coming from natural resources and biodiversity.

Mr Thiaw concluded that healthy soils are one of the best insurance policies for communities facing water scarcity. Mr Thiaw emphasized, in simple words, that ' Soil is life'.

Minister of Environment and Energy of Costa Rica – H.E. Carlos Manuel Rodriguez

Mr Carlos Manuel Rodriguez emphasized that to promote healthy soils on a global scale, the conceptual and institutional barriers between Ministries of Environment and Agriculture must be overcome. The division between environment and agriculture hinders the scale of success of RECSOIL and other soil initiatives. Both sectors have been highly effective as separate agencies working towards the same goal, but with different perspectives—to conserve biodiversity. Mr Rodriguez addressed the need to develop science, an area in which FAO already plays an important role with soil data and information and should continue to provide technological support to countries to enhance their capacities. Mr Rodriguez explained that in order to create an international market for carbon in the soil, it is necessary to build a national mechanism, similar to Costa Rica’s Payment for Ecosystem Services programme, initiated in 1997. Mr Rodriguez mentioned that the creation of a tradable carbon credit on the international market requires institutional capacity, political engagement, and FAO's support. Narrowing the gap in terms of vision and action with the two agencies is critical in this soil conservation effort. In particular, Mr Rodriguez noted that RECSOIL is a cohesive tool to bring ministers together to share a similar vision of sustainable landscape management.

Mr Rodriguez emphasized that the post-COVID19 context is an unprecedented opportunity to move away from unbridled growth at all costs: economic systems, oil fuel economy, deforestation and soil degradation, and to achieve a sustainable balance among people, prosperity and our partner countries.

Keynote presentations

Status and challenges of global soil organic carbon sequestration – Professor Rattan Lal

Professor Rattan Lal, Distinguished University Professor of Soil Science and Director of the Carbon Management and Sequestration Center, introduced the status and challenges of global soil organic carbon sequestration. Professor Lal began by describing that the soil carbon stock is divided into two components: organic and inorganic (mainly in drylands). He explained that the SOC stock in 1-meter depth is more than twice the total stock in the atmosphere. He mentioned that if a depth of 3 meter is taken, the organic stock is approximately 3.000 gigatons. Professor Lal pointed out that similar data is needed for the inorganic carbon stock, and he asked the GSP to create this map and database.

Professor Lal explained that the technical potential for carbon sequestration in soils and vegetation by 2100 is 333 Petagrams (Pg). He concluded that achieving half of this target will benefit the world as it could reduce the rate of global warming.

Professor Lal explained that to measure SOC for carbon trading, quality, depth, frequency, precision, and scale are essential, as are the measurement techniques developed in national laboratories. He suggested expressing carbon stocks in volume as a better option; however, this requires further research.

He emphasized that due to soil erosion, the organic fraction is displaced, leading to emissions, including in wetland and riverine areas. However, it is unclear what happens to the large amount of carbon that ends up in rivers, oceans and lakes. Professor Lal explained that understanding carbon dynamics on the deposition side is another crucial challenge that FAO/GSP and UNCCD can address.

Professor Lal concluded by proposing research topics to determine the rate of SOC and SIC sequestration and management practices that can achieve and determine the importance of economic sustainability in relation to soil productivity, food security, and halting degradation.

Is soil organic carbon sequestration really feasible? How to scale it up? – Professor Pete Smith

Professor Pete Smith, Professor of Soils and Global Change, Aberdeen University, and Science Director of Scotland's ClimateXChange, addressed the question of whether soil organic carbon sequestration is feasible and how to scale it up**.** Professor Smith explained that soil organic carbon sequestration is feasible and the potential is immense. To gain additional storage potential, it is important to consider natural or nature-based climate solutions, which figure prominently in policy debates.

Professor Smith indicated that carbon sequestration has limited downsides, making it beneficial for multiple ecosystem services and contributing to the achievement of the Sustainable Development Goals. He emphasized the need for further research and a robust

monitoring, verification, and reporting framework to increase carbon gains and address the limitations of soil carbon sequestration.

Professor Smith believes it is possible to scale up. However, at the individual farmer level, the implementation procedure must ensure that farmers overcome the barriers—institutional, educational, economic, and cultural—that prevent them from adopting better management practices. Professor Smith indicated that all practitioners need to be aware of all the barriers that prevent farmers from making a change and target policymakers to help overcome the problems, and how to implement management practices, and provide the enabling conditions for farmers to realize the potential.

In the framework of RECOSOIL, Professor Smith emphasized that soil carbon needs to be appropriately monitored, reported, and verified on a global scale.

Soil organic carbon sequestration: experience from the ground – Ms Maria Beatriz Giraudo

Ms Maria Beatriz Giraudo, an Argentinian Farmer, shared her experience in the field. She began by thanking the GSP Secretariat for the hard work on the new RECSOIL initiative. Ms. Giraudo recalled that for 30 years in Argentina, soil erosion was a problem caused by wind and water as a result of intensive tillage. Ms Giraudo explained that in order to solve this disruptive issue, a group of farmers had created a new paradigm. The farmers changed the farming techniques, choosing the opposite direction (no tillage) to recover and improve the soil. Ms Giraudo emphasized that the key point of the massive adoption is that it all started with farmers; farmers trust farmers, they have the same perspective and the same goals. Ms Giraudo indicated that the implementation of the new approach has reduced physical, chemical, and biological degradation of soils and promoted carbon sequestration, which has enhanced resilience.

In addition, Ms Giraudo described the chakra farming system, an innovative applied research programme in which farmers and scientists discuss and carry out field trials with the support of scientific institutions, universities, and experts. She mentioned that the RECOSIL initiative could build strong networks with farmers and place farmers at a high level of discussion with scientists and policymakers.

Ms Giraudo explained that although the COVID-19 pandemic slowed down the global movement and circulation of products, agriculture is one of the few sectors to continue its activities.

Unlocking the potential of soil organic carbon: RECSOIL – Ms Rosa Cuevas/Mr Ronald Vargas

Ms Rosa Cuevas and Mr Ronald Vargas, GSP Secretariat, FAO, underlined RECSOIL as a response for action. Ms Cuevas noted that, according to the Status of the World's Soil Resources Report, soil is a valuable natural capital on which humans and all life on Earth depend. According to this report, 33% of our soils are degraded due to 10 major threats that affect their functions, jeopardizing the provision of essential ecosystem services. Ms Cuevas pointed out that land-use change results in the emission of billions of tons of carbon into the

atmosphere. Land degradation caused by poor management, such as the misuse of fertilizers land-use change, excessive use of agrochemicals, and monocultures leads to high rates of erosion and loss of biodiversity, thus negatively contributing to climate change. Ms Cuevas noted that although all ecosystem functions and services rely on soil organic carbon content, no global effort has been made to put soil and its carbon as a key element in the fight against climate change, degradation, biodiversity loss, and food insecurity.

Ms Cuevas explained that it has become clearer since the establishment of the Global Soil Partnership in 2012 that it is important to maintain and increase SOC stocks as a cost-effective option to combat climate change degradation, biodiversity loss and food security.

She asked: 'How can we create an enabling environment for scaling up sustainable soil management practices based on soil organic carbon sequestration?'. To answer this question, Ms Cuevas cited a number of barriers, including uncertainty about the additionality/permanence of SOC, lack of technical support and financial incentives for farmers among others. Ms Cuevas concluded by introducing the RECOSIL initiative.

Mr Ronald Vargas presented the components of RECSOIL and how it is intended to work. He explained that FAO/GSP, in collaboration with all partners, are developing the GSP toolkit, which includes various tools to address the challenge of increasing and scaling up soil organic carbon sequestration. It is important to understanding the global potential of soil organic carbon sequestration, and countries will receive training to prepare their own national maps on SOC sequestration potential. This will then guide RECSOIL actions on the ground. The first step in the implementation of RECSOIL on the ground is to reach an agreement among farmers and RECSOIL to work together, farmers will then have access to technical support and financial incentives to adopt the best practices adapted to their local conditions and crops. In order to measure the sequestration of the SOC, an eight-year cycle with baseline measurements after 4 years and at 8 year will be done. The measurement is not only for SOC but also for other indicators that demonstrate improvement in other soil functions/ecosystem services. Once the cycle is complete, investors who do not require carbon credits will just receive a report on the enhancement of soil properties, including SOC, and crop production will be compliant with the Voluntary Guidelines for Sustainable Soil Management, allowing them to obtain the label for their products. For those who require carbon credits, RECSOIL will facilitate the issuance of carbon credits by accessing the current voluntary carbon marketplace.

Panel session - Moving the SOC agenda into action:

Secretary General, World Farmers Association – Ms Arianna Giuliodori

In your experience, what are the main barriers that prevent farmers from widely adopting sustainable soil management practices? Will the provision of technical support and financial incentives to farmers increase the adoption of good practices?

Ms Giuliodori indicated that all farmers around the world are deeply interested in promoting the quality of their most important production factor, the soil. Ms Giuliodori indicated that the main discussion should focus on creating opportunities for farmers to deploy the potential they see because farmers are economic actors. The question is how to better shape the market to fairly value the role of farmers that apply sustainable management practices. Ms Giuliodori concluded by appreciating the RECSOIL initiative which creates an opportunity to repay the farmers for their investment. In addition, RECSOIL can create a strong farmers' organization and advisory services that can support the transition and change that is needed and share the deep commitment that exists in the farming community.

Global Lead, Technology-Innovation-Climate Smart Agriculture, World Bank Group – Mr Eric Fernandes

What are the Word Bank's actions with respect to service and sequestration? Is there a financial scheme for scaling up the generation of carbon credits from sustainable soil management?

Mr Eric Fernandes, Global Lead, Technology-innovation-Climate Smart Agriculture, World Bank Group, informed that the World Bank is a global development agency that collaborates with governments and national institutions. The World Bank provides financing, technical assistant, and partnerships. Mr Fernandes emphasized that the bank is fully committed to supporting all causes related to sustainable soils and agriculture. By 2020, about 53% of all investments in the 20 billion agriculture portfolio are targeted at the core benefits of adaption and mitigation—the goal is to increase this share to 66% by 2025 and directly involve 20 countries with about 10 million farmers—on landscapes. Mr Fernandes stressed that these points need be integrated into global commitments and ongoing dialogue. At COP 24, the World Bank Group announced climate targets for 2021-2025 and doubled its current and five-year investments to around 200 billion—as a new commitment. 133 billion to deepen the mainstreaming of climate change, of which 50 billion for adaptation, sustainable land management and recarbonization are key priorities. In addition, 67 billion is dedicated to mobilizing private financing.

In conclusion, Mr Fernandes explained that in terms of technical assistance since 2014, the World Bank has released about 30 climate-smart agriculture profiles around the world to help country partners and farming communities understand the challenges and opportunities for food systems and agriculture. Lastly, the World Bank is currently involved in the development of climate-smart investment plans for approximately 2.5 billion.

Policy officer, DG Clima, European Commission – Ms Christine Mueller

What are the main achievements of carbon farming, based on this experience, should we move forward with RECSOIL?

Ms Christine Mueller informed that the key issue is the political recognition that the European Union has given through the European Green Deal as a flagship soil carbon initiative and the importance for global sustainability in general and for healthy food biodiversity and climate mitigation and adaptation. The European Union aims by 2023, to create rules for the certification of carbon removal that include a nature-based solution—which would be

science-based. Ms Mueller explained that the European Commission has designed a joint research partnership, which includes experts in agricultural soil research and is supported by all Member States and those responsible for implementing agricultural policy. Moreover, it is stipulated throughout the whole arrangement that the research must be closely geared to the needs of farms.

Ms Mueller mentioned that the European Union has more than 60 years of experience in agricultural policy, considering that it has a sound administration and information system, which are excellent preconditions for launching carbon farming initiatives in Europe. Ms Mueller explained that the European Union is currently working on the SoCal farming guidelines that will be launched in November and on the creation of a system to facilitate carbon farming through an improved knowledge system. She informed that the aim is to create an information system with modern information technology tools and make it available to farmers, public authorities and other stakeholders. In addition, the European Union plans to conduct a pilot project on wetlands. To conclude, Ms Mueller stated that the European Union fully supports the RECSOIL initiative.

Strategy Lead Agriculture at Microsoft – Mr Barney Debnam

Can you please let us know what Microsoft's strategy towards carbon neutrality is? What is the role of soil organic carbon there?

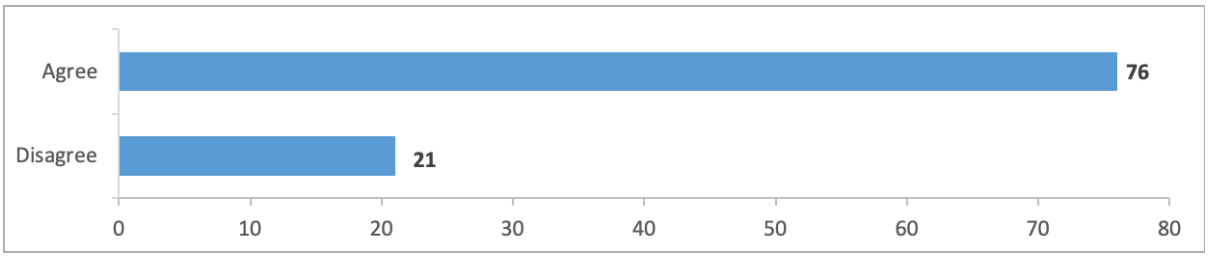
Mr Barney Debnam, Strategy Lead Agriculture at Microsoft, indicated that Microsoft is committed to being a carbon-negative company by 2030 and to eliminating all carbon emitted into the environment by 2050 since the company was founded in 1975. Mr Debnam mentioned that Microsoft has committed $1 billion to study natural and new technologies for sequestration and removal. Mr Debnam indicated that Microsoft and other technology companies believe that digital technology has an important role to play and can create a scalable solution that benefits society and the RECOSIL initiative.

In closing, Mr Debnam noted that Microsoft has created an *AI for Earth program* that provides grants for researchers and organizations that monitor, model, and manage Earth's natural systems. The grant focuses on four main topics: climate, agriculture, biodiversity, and water.

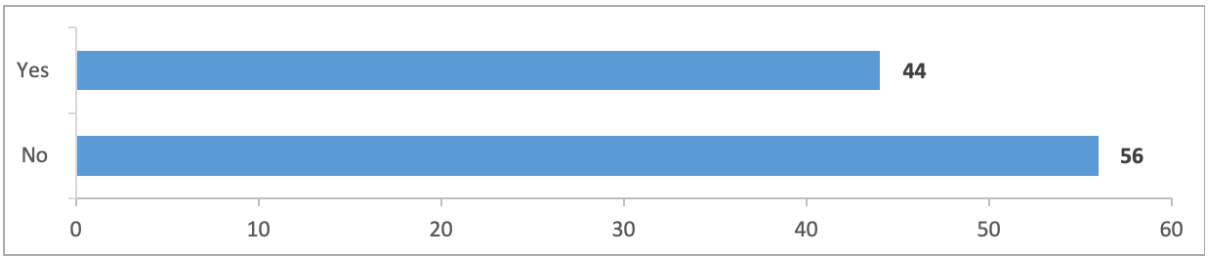
Interactive session - Polls

During the presentations, an interactive session was launched with five poll questions posed to participants as followed.

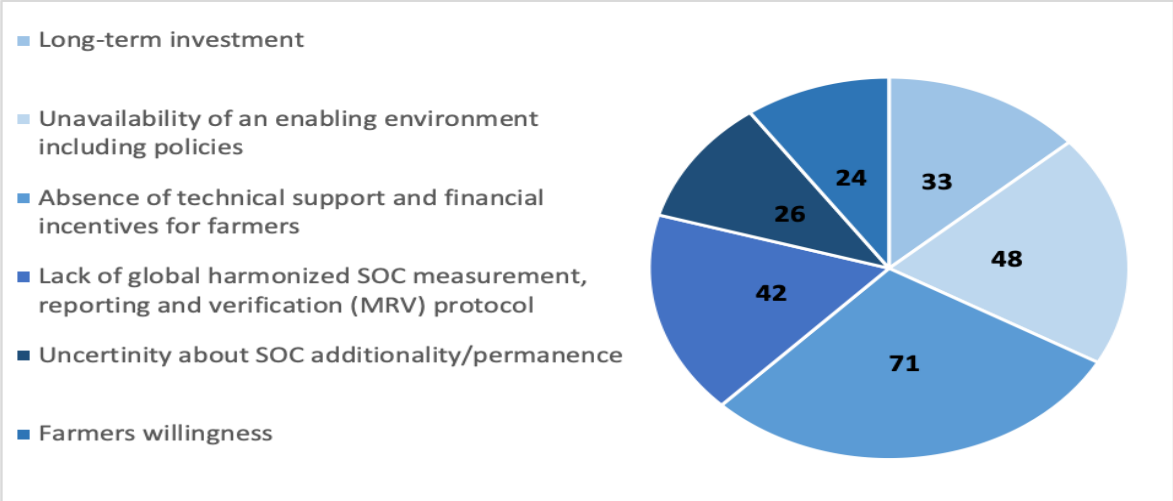
Question 1: According to the IPCC report, organic carbon has been identified as one of the main cost effective options for climate change adaptation and mitigation, as well as for combating Desertification, land degradation, and food security. Do you agree with this statement?



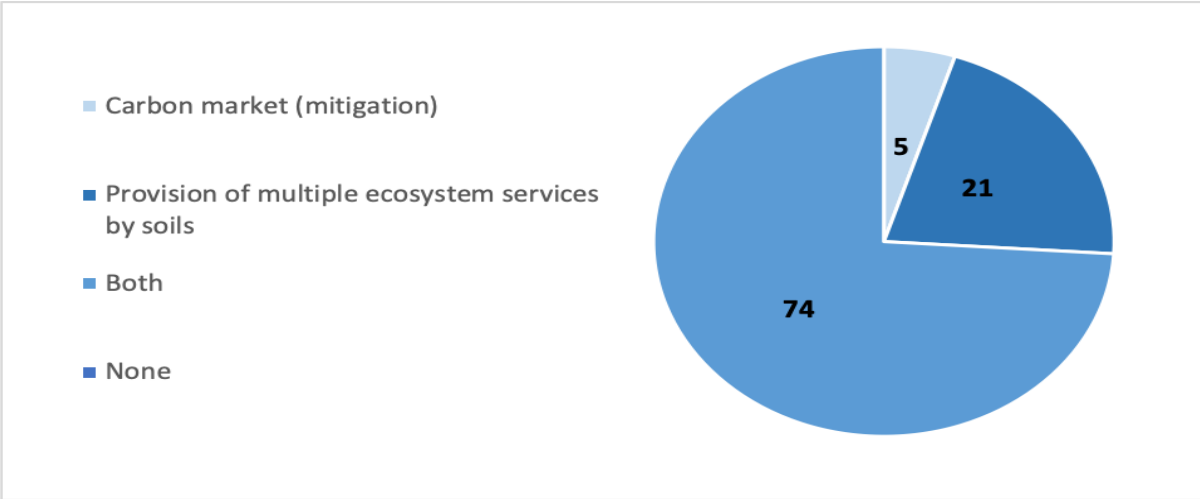
Question 2: There are some contradictory positions indicating that SOC sequestration is not a feasible option for large scale emissions reduction but mainly for enhancing soil health. Do you agree with this statement?



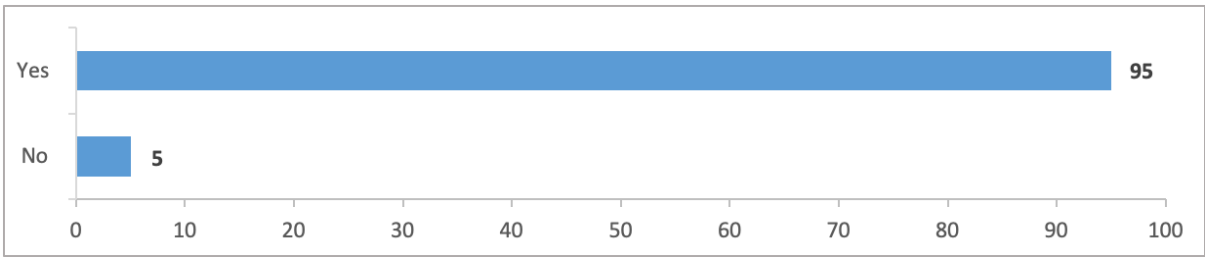
Question 3: What are the two main barriers for scaling up SOC sequestration? (Multiple choice)



Question 4: In your opinion, the Global Soil Organic Carbon agenda should be oriented towards:



Question 5: Do you think RECSOIL constitute a viable response to the scaling up of sustainable soil management centered on SOC sequestration?



Conclusion - Deputy Director General, Climate and Natural Resources, FAO – Ms Maria Helena Semedo

Ms Maria Helena Semedo recognized Professor Rattan Lal for his award, on his outstanding and dedicated work on soils. She emphasized that cooperation and collaboration on soil continues to excel on the international agenda. Ms Semedo briefly summarized the main issues mentioned in the panel, focusing on the challenges ahead for food security, sustainable agriculture, healthy soils, and soil organic carbon.

Ms Semedo concluded with the key message that there is a need for partnerships between science, government, private sector, civil society, but most importantly, farmers. Farmers are at the forefront of food production and are directly witnessing the effects of climate change. They must be supported by policies and investments, and enable environments to produce sustainably.

Annex 1 | Question and answer

Disclaimer: *The questions and comments reflect exactly what participants wrote in the chat and the Secretariat did not edit them to respect the originality of them. The answers represent the views of the speakers and do not represent FAO's position/view.*

To the Global Soil Partnership

1. **Can we conclude that soil carbon sequestration is directly Organic Farming?**

Soil organic carbon (SOC) sequestration is caused by management practices that add high amounts of biomass to the soil, causing minimal soil disturbance and enhancing several soil functions and ecosystems services such as water retention, soil structure, nutrient cycling and availability, biodiversity, among others. SOC sequestration is the basis of organic farming.

2. **Is there any program now to recompense to farmers?**

Some countries have programmes to increase farmers' revenues. The RECSOIL Programme has drawn the best experiences from these.

3. **Any remote sensing method to measure soil organic carbon?**

Most satellite remote sensing (RS) methods use RS as covariate rather than replacing soil measurements. RS is very effective for viewing above ground carbon. Hence, the relationship between RS and aboveground carbon is promising and have been widely used to support mapping of SOC. For proximal remote sensing, spectroscopy (near infrared-NIR and mid infrared-MIR) is well tested for carbon concentrations.

4. **How can we improve the Remote Sensing Techniques for SOC measurement?**

- For soil spectroscopy: more bands of scanning to obtain a better spectral signature, improved calibration libraries and prediction algorithms.
- If spectroscopy is performed in the laboratory: improvement of soil preparation procedures;
- If spectroscopy is performed in the field: improvement of the compensation procedures for soil moisture and structure.
- Satellite and airborne remote sensing cannot be used directly for measurement of SOC, but can be useful as predictors (along with terrain, climate and others) for mapping spatial distribution of SOC, given ground-measured samples are available.

5. **How to access RECSOIL toolkit for applicative in farmers of north of Peru?**

The RECSOIL toolkit is under development and will be available on the GSP page in late 2020. The components are:

- Global Soil Organic Carbon Map (GSOC map).
- Global Soil Organic Carbon Sequestration Potential Map (GSOC seq).
- Voluntary Guidelines for Sustainable Soil Management (VGSSM).
- Best soil management practices for SOC maintenance and sequestration: a technical manual (to be released soon).
- GSOC-MRV Protocol: A Protocol for Measurement, Reporting, Verification and Monitoring of Soil Organic Carbon in Agricultural Landscapes.

- Global Soil Organic Carbon Monitoring System
- RECSOIL Programme roll-out and farmer financial support.
- Protocol for the Assessment of Sustainable Soil Management (SSM).
- The international Code of Conduct for the sustainable use and management of fertilizers.

6. **How can farmers be part of RECSOIL to receive technical input and financial assistance? I am sure many farmers here in Kenya would be keen to be part of it.**

As of 2021, the RECSOIL Programme will be launched and will be accessible through interested farmers' associations. We will be sending news to all participants of this webinar and others, so all details will come at the beginning of 2021.

7. **How can we promote RECSOIL program amongst our farmers?**

- Dissemination of the RECSOIL Programme through farmers' associations at national level.
- Workshops and meetings.
- Through the FAO Representations in each country.
- Dissemination materials on RECSOIL will be available so, you can use them for sharing them with farmers.

8. **What is the process of applying for RECSOIL program?**

The RECSOIL programme will be rolled out in 2021. Clear information on the application process will be made available in our website at the beginning of 2021.

9. **How does an individual/small farmer sign up or pursue this?**

Under RECSOIL, all interested farmers can participate, provided that their soils are technically feasible for SOC sequestration. Preferably, farmers will work within RECSOIL in the framework of Farmers' associations.

10. **Is it possible to buy Soil Carbon credits (A policy by which farmers will be given incentives, for the amount of carbon they fix in their farm in a year)?**

This is one of the main objectives of the RECSOIL programme. The GSOC-MRV Protocol suggests a minimum project cycle of eight years, with 3 measurements and payments in the first, fourth and eighth year respectively.

11. **What is the process to arrive at farmer to farmer level and what are the next step?**

Through farmers' associations at the national level. Within RECSOIL we will contacts with farmer associations, however we have a programme called Soil Doctors Global Program that it is a farmer to farmer extension service.

12. **Do you not consider microbial necromass carbon? Why not?**

The GSOC-MRV Protocol contemplates conventional measurements involving the total fraction of carbon in the soil. If you want to see short-term changes (in two years) associated with management practices, the protocol suggests analysing carbon in particulate organic matter - which includes microbial biomass- as this is a labile fraction and therefore a more sensitive indicator to management practices.

13. Which companies do you think show the most promising approaches to commercialization of SOC by certifying Carbon credits?

Currently, there are many initiatives aimed at the voluntary carbon market. Some of the best know companies/initiatives working on it are VCS, VERs and Carbon farming initiative.

14. Can we achieve zero nutrient depletion through soil carbon sequestration?

Nutrient depletion in the soil depends on many factors, including organic matter content. It is also related to the mineral composition of the soil, the crop management history and the climate conditions. In a soil with a very low content of nutrients and micronutrients, carbon sequestration is not enough to meet the balanced nutrition crop needs.

15. How much carbon can a soil store and how can its capture potential be increased?

The magnitude of SOC storage is variable in space and time and determined by different fine-scale interactions such as microbial activity, mineral clay interactions, organic matter decomposition rates, and land-scale factors such as climate, vegetation type, soil type and topography, which means that not all soils can sequester carbon, not all at the same time and not all under all conditions.

To ensure SOC sequestration we need to adopt sustainable soil management (SSM) best practices and robust methods for monitoring carbon over time (such as GSOCmap, GSOCseq, GSOC-MRV Protocol, etc.). To scale up such SSM practices, it is essential to give incentives to farmers through mechanisms such as RECSOIL.

16. What do you consider shorter-term experiments? Days, weeks, months?

We consider short-term experiments to be those with a time-span of 3-5 years, in order to be able to detect changes in labile fractions (particulate organic carbon), or in total soil organic carbon in some specific soil types and production systems.

17. Capability of Remote Sensing for mapping Soil Organic Carbon?

Remote sensing data is one of the main predictors used in digital soil mapping of SOC. The spectral reluctance of the bare soil surface has clear links to the SOC content in the topmost layer of soil. However, such a relation can usually only be applied for mapping small areas (such as one field), due to the difficulty of having a coherent set of bare soil images for large areas (such as regional, national or global mapping). It should also be noted that the relationship between bare soil reflectance and SOC must be calibrated individually for each study area, as these relationships are strongly depend on other soil properties such as structure, moisture, texture, iron content, etc.

Another issue is that remote sensing only grasps the surface of the soil (penetrating down to few centimetres in case of radar data). Vegetation indices (such as NDVI, SAVI, EVI, etc.) provide information on the spatial variability of biomass production, and can therefore be used as one of the proxies for modelling SOC. However, it should be noted that not all biomass contributes to the accumulation of SOC in soils, especially in agricultural lands.

Therefore, direct measurement of SOC from remote sensing data alone proves to be practically impossible. However, when combined with field measurements of SOC, as well as with other environmental data such as terrain parameters, climate data, geology, soil maps, etc., remote sensing becomes a valuable asset in modelling spatial distribution of SOC.

Another point concerns the proximal sensing techniques used in laboratory measurements of SOC, such as soil spectroscopy. With adequate calibration and rigorous

procedure of sample preparation, soil spectroscopy can be used to measure soil samples and determine SOC with relatively high confidence.

18. Is the 4 per 1000 C increase goal realistic for all situations?

Paul Luu, Executive Secretary of the 4 per 1000 Initiative *dixit*: "While pursuing the indispensable effort to drastically decrease the greenhouse gases (GHG) emissions due to human activities, increasing soil organic carbon sequestration could make a substantial contribution to GHG mitigation efforts. A theoretical annual increase of the world soil organic carbon stock by 0.4% of its value would be larger than the 2015 annual increase in CO2¬ in the atmosphere, which is a major contributor to the greenhouse effect and climate change : this is the origin of the "4 per 1000" title of this initiative."

This is only an inspirational goal that indicates in which direction we must go, using agriculture and forestry to contribute to the mitigation of climate change, to help adapt agriculture to climate change and thus to increase food security. That means a win-win-win situation. We have never said that the figure of "4 per 1000" should be taken as a precise goal to be achieved everywhere on earth. We know perfectly well that in some place this ratio will be overtaken, while in other places it will not be reached.

So the answer could be "no", but as you can see, the answer is not that simple. The Initiative name is just an incentive to act, because after all, 0.4% (that means "4 per 1000") is not much, and it helps us all to believe that we can act, that it is not too late, and that we have to do it.

19. Which policies and regulations do we have currently to promote the increase the organic carbon in the soil? Is not the nitrate directive limiting the amount of carbon we are adding to the soil?

There are no global policies and regulations in this sense. However, some countries have programs that promote SOC increase. In general, policies aiming at soil erosion control, prevention of deforestation, and promotion of crop rotations and more crop diversification and integration between production systems are aligned with SOC increases.

Regarding the second question, the Nitrate Directive aims at reducing water pollution caused or induced by nitrates from agricultural sources. The nitrate concentration limit is above 50 mg/l in freshwaters or eutrophication. Agricultural areas that drain into these waters and contribute to pollution should be designated Nitrate Vulnerable Zones (FAO, 2003). We are not sure that the Nitrate Directive has established similar guidelines in the case of soil carbon amendments.

20. Is there a practical way or technology for measuring the degree of soils' decarbonization?

The GSOC-MRV Protocol is intended to measure and model soil organic carbon stocks and its changes through time. These changes can be positive (recarbonization) or negative (decarbonization). Therefore, although the methodology is oriented to be applied in fields that incorporate sustainable soil management practices, potential and current negative SOC changes can be assessed using this protocol.

21. Is there any reliable data available to assess soil organic carbon dynamics over agricultural areas in Kenya for the last say 50 years? I would like to do this to inform future soil carbon restoration initiatives.

A global dataset (GSOCmap) is available to extract soil organic data for Kenya. The raster dataset is available here. The dataset is a country driven dataset and the SOC Map of Kenya has been provided by the Kenyan government. Behind the map, there are 2059 soil samples collected over the period 1976-2017. GSP is only distributing the raster dataset as derived data, but not point data. Our national counterpart below holds the point data:

- Data Holder: Kenya Agricultural and Livestock Research Organization
- Contact: Peter Kamoni, Matolo Nyamai Peter kamoni (pkamoni@gmail.com) and Matolo Nyamai (matolonyamai@gmail.com).

22. **Recarbonization of global soils can be or it is a strategic response to soil degradation and climate change. What are communities (smallholder farmers) doing to recarbonize soils using natural resources available to them such as forests?**

In many parts of the world, small-scale farmers are doing different things to integrate organic matter and biomass into their soils, such as composting, use of crop's stubble, among others. A successfully example of how sustainable soil management can deliver results is the Quesungual System. See the following links:

- http://www.fao.org/soils-2015/news/news-detail/en/c/318676/
- http://www.fao.org/3/a-at763s.pdf
- http://www.fao.org/3/i9076es/I9076ES.pdf

In general, farmers are aware of this, the main problem is that in many cases they require technical and financial support in order to implement such practices.

23. **I feel sad because my country Kenya, is working on a New Bill to ban use of organic manure in agriculture. I obviously find this an upside-down policy and not informed by science or rather ignorant about scientific evidence on how organic manure is important for agriculture and climate change mitigation in general. What is FAO doing about such downward policies?**

FAO promotes and advocates sustainable soil management through normative tools such as the World Soil Charter, the Voluntary Guidelines for Sustainable Soil Management and the International Code of Conduct for the Sustainable Use and Management of Fertilizers. We disseminate them and advocate for their implementation at the national level. Each country has the sovereignty to adopt these tools or to develop legislation according to its interests. We will inform our office in Kenya to ensure follow-up.

24. **Is it reasonable to talk about C sequestration without considering N cycle in soil? Since these two cycles are "coupled" and then to store C, surely N is needed.**

It is known that the carbon and nitrogen cycles are coupled. The availability of N and the stoichiometric balance (C:N ratio) are key factors that control plant growth and soil processes. Since nutrient availability directly affects biomass production and decomposition processes and eventually, SOC sequestration, it should be considered in the soil re-carbonization process in the future.

Synergistic effects should also be considered in the case of nitrogen additions. For example, if the increase in SOC is promoted, it may have beneficial effects on soil aggregation and microbial activity, and eventually on soil carbon storage. However, if nitrogen additions continue in the same crop or if nitrogen fertilizers are added to nearby plots without considering good management practices, nitrous oxide emissions could offset between 56 and

61% of the CO_2 reduction associated with C sequestration in no-till plots (Grandy et al. 2006). In the case of agricultural soils, additions of N should be carried out within a framework of good practices, if possible taking into account the recommendations of the International Code of Conduct for the Sustainable Use and Management of Fertilizers.

Due to the above, although RECSOIL is a carbon-focused initiative, it could be more inclusive in the future. However, it is also true that more insights are needed to better understand and predict the synergies between carbon and nitrogen and the effects of their interactions on soil carbon sequestration.

25. **How Carbon stock could be increased in intensively cultivated?**

Intensive farming tends to decrease carbon stocks; to increase them, sustainable management practices must be implemented. Please see the following link: http://www.fao.org/documents/card/en/c/5544358d-f11f-4e9f-90ef-a37c3bf52db7/

26. **Are there trade-offs between Food Security, livelihoods and the proposed SOC sequestration? If yes, this speaks to the core issue HE Rodriquez mentioned on the mental and institutional barriers between the MoE and MoA.**

SOC sequestration increases soil productivity, therefore more food, but also more nutritious. This can help increase farmers' income as well. On the other side, SOC sequestration helps to enhance soil biodiversity, which has positive impacts on aboveground biodiversity. H.E. was referring to the lack of coordination and common vision by the Ministries of Agriculture and Environment, but in the end, they are working for the same with a slightly different focus.

27. **I feel like we often try to find reasons to justify why farmers don't adopt new strategies without questioning whether or not these strategies are relevant for the farmer... Does it fit in their world vision, their ways of understanding the world, their own objectives?**

Sustainable soil management has been an ancient tradition adopted by many cultures. This is very relevant because healthy soils are more resilient to adverse climatic conditions and more productive, which translates into higher incomes for farmers and a better quality of life. Sustainable soil management has positive implications for farmers, for the environment and for society (more nutritious food).

28. **"The practices grouped as regenerative agriculture can improve soil health and yield some valuable environmental benefits but are unlikely to achieve large-scale emissions reductions." WRI Report. Policy makers need to be clear on their objectives: soil health, GHG emission reductions, farmer livelihoods, food security?**

This topic has recently been debated and rebutted. Programmes like RECSOIL help decision makers understand that if a soil is well managed, it will increase its carbon stocks and this will bring multiple benefits to the environment and society. In addition to GHG mitigation.

29. **My question is in terms of the availability of funding opportunity from FAO to the countries in Partnership. If there, is any funding opportunity for the soil management intervention? How potential NGOs apply for it?**

Usually FAO works with NGOs for the implementation of certain actions, especially at the field level, so you need to check for opportunities at the FAO national office. The RECSOIL

programme is especially designed to mobilize resources for investing in field activities. Here, NGOs can play a role.

30. **Carbon stocks increase significantly down to and below 3 M? How do we measure this and at what depths?**

The GSOC-MRV Protocol is intended to be widely applied, technically feasible and cost-effective. We are aware that SOC changes can occur below 1m, up to 3 m or more. Farmers/project proponents are encouraged to monitor SOC stocks at deeper layers, depending on local information/expertise. However, in order to standardize procedures and to reduce laboratory and field monitoring costs, considering that the MRV is intended to be applied on a farm scale, a 0-30 cm depth is set as the minimum depth to monitor SOC stocks and changes.

31. **It appears that the chemical mindset still overwhelms the needed biotic mindset. Why aren't we focusing on the life in the soil?**

The "biotic mindset" is increasingly gaining the attention of different stakeholders, from farmers to policymakers. However, the transformational change is a long-term process. The Green Revolution took time to be established because there are many variables involved, including feasible solutions in the field, mindset and systemic change, and social pressure. One of the barriers that we still have is the effectiveness of new bioproducts compared to chemical products. For instance, the application of commercial pesticides (which includes herbicides) can simplify the process, but at the same time, it can have multiple negative implications. The biotic pathway is clearly a more sustainable option, in which biodiversity is the engine behind soil health and sustains life on this planet (providing a range of ecosystem functions and services which include the carbon cycle). The good news is that technology combined with traditional knowledge is supporting a transition that is already underway.

32. **I do agree we know the problems and solutions. My question is how do we streamline practices and technologies in short term given the urgency of soil losses? What are the incentives available to smallholder producers to embrace the change?**

There are interesting positive experiences on the ground in terms of adopting good practices. So, the technical know-how is there. We are currently in the process of documenting it so that we could have a manual of good practices. Some countries are already working on providing payments for ecosystem services, so this is not new. RECSOIL will focus on that.

33. **In Bolivia, we have two agricultural sectors, that of the small farmer and the agro-industrial sector. BOTH with different interests. How to reach both with the same effect?**

The RECSOIL Program has two main mechanisms:

- RECSOIL Trust-Fund to support subsistence farmers: they will accomplish multiple ecosystem benefits (including SOC sequestration) but we will not issue carbon credits. A Label of compliance under the Voluntary Guidelines for Sustainable Soil Management (VGSSM) and RECSOIL will be provided.
- RECSOIL in the Voluntary Carbon Market (using private investments): generation of carbon credits for the Voluntary Market and/or carbon pricing mechanisms under national schemes.

34. **Reduced the NUMBER of pesticides? What about quantity and risk?**

Pesticides have greatly contributed to crop intensification and the reduction of world hunger. However, highly toxic and persistent compounds have been used, causing damage to soil organisms, terrestrial and aquatic ecosystems and human health. Today, industry and governments are making great efforts to develop less hazardous and more specific compounds and to regulate the entire life cycle of pesticides, from their manufacture to their purchase, use and disposal, in order to reduce risks to the environment and human health. RECSOIL promotes nature-based solutions, such as integrated pest management, but it is clear that in some cases synthetic pesticides are still needed, so less harmful formulations need to be promoted. Raising awareness and informing farmers is also essential to change the "more is better" mentality, so that they are better able to choose the most suitable and adapted pesticide for their needs and apply it at the right time and in the right quantity.

35. **Regarding novel (anaerobic digestate, biochar, new waste streams) and traditional (eg raw manure) soil amendments (both soil improvers and fertilising/nutrient providers), which is the role you foresee of these in soil recarbonization? Is material type + soil nature/conditions the main agents or management or both? Which would be the research gap/aspect you consider is of outmost importance, especially concerning the inorganic waste streams application to soils?**

The protocol considers the application of organic amendments (digestates, biochar, wastes, and manure) as sustainable soil management practices, whenever these organic materials are not currently being applied to the soils. This is to ensure additionally of the proposed practices, and to avoid 'leakage' risks (i.e. residues that are already being applied to a specific field are now removed from that field and are applied to a different field, with no net change in the overall carbon budget).

The GSOC-MRV Protocol is intended to monitor changes in management practices to increase SOC stocks and reduce GHG emissions (by reducing SOC losses, increasing carbon input to soils, reducing GHG emissions, or a combination of these), under the soil/climatic conditions were the field is located.

One of the main research gap is to determine whether these organic/inorganic amendments generate additional GHG emissions or negative effects such as groundwater pollution.

36. **Should be have a policy guideline and long-term SOP for Farm management in order to improve long term Ecosystem services and benefits?**

Since 2016, the GSP launched the Voluntary Guidelines for Sustainable Soil Management in order to provide general technical and policy recommendations on sustainable soil management for a wide range of committed stakeholders.

37. **Can we take 30 cm stock as soil carbon sequestration? If not, what is the depth of soil if farmer want to join in carbon trading?**

The GSOC-MRV Protocol is intended to be widely applied, technically feasible and cost effective. In order to standardize procedures and to reduce laboratory and field monitoring costs, considering that the MRV is intended to be applied at the farm level, a 0-30 cm depth is set as the minimum depth to monitor SOC stocks and their evolution. Farmers/project proponents are encouraged to monitor at deeper soil layers if there is evidence/local expertise considering that SOC changes are expected in soil layers deeper than 30 cm.

38. **What is your opinion about the possibility of soils having a maximum sequestering capacity?**

Soil organic carbon loss is the second biggest global threat to soil functions. Having a maximum sequestration capacity would imply that soils with this potential would capture the estimated 135 gigatons released into the atmosphere since the preindustrial era. On the other hand, sequestration capacity depends on various edaphoclimatic factors and the inherent soil's capacity of saturation.

39. **Prof Pete Smith mentioned mechanisms being developed in the context of RECSOIL to ensure additionality and avoid leakage - could you provide more specific details of these mechanisms. Thank you, and thanks for the excellent presentations.**

A preliminary assessment of the additionality of the projected management practices is included in the GSOC-MRV Protocol. Based on the activity data provided (current and projected crops and yields, fertilizer doses, residue management, etc.), SOC stocks and GHG emissions of the current and projected practices are estimated using modelling approaches, prior the introduction of management practices in the field. Using the guidelines provided in the GSOC-MRV Protocol, additionality is then numerically assessed: how much carbon would be sequestered in soils and how much GHG emissions would be reduced, compared to a situation where the proposed technologies or changes would not have existed.

This Protocol does not apply if leakage due to land use changes is expected to occur. For example, a project that aims to convert areas of croplands to permanent grasslands in order to enhance SOC sequestration but indirectly results in deforestation or conversion of other grassland areas to cropland in a region or area outside the declared boundaries, will result in leakage. Potential sources of leakage other than land-use changes shall be outlined in the initial project description phase.

40. **Is there any solution to process the straw after harvest instead of getting burn?**

Straw can be left on the surface (crop residue); this will protect soil from sun radiation and rain impacts (or just external/ abiotic factors such as erosion etc.). For the next crop, direct seeding is common practice and the straw or other crop residues will be integrated into the soil organic matter. These concepts are referred to as crop residue and green manure once the residues are incorporated into the soil.

41. **Permission to ask, with the existence of a covid-19 pandemic, what RECSOIL is safe and can also be used by farmers to support this?**

RECSOIL respects bio-security measures at global, national and local levels, thus it does not imply any risk and will be implemented only when safety is guaranteed.

42. **Can we make an effective shift in SOC with 2-yr on-farm trials?**

No, the GSOC-MRV Protocol, suggests a minimum project cycle of eight years, with 3 measurements in the first, fourth and eighth years respectively.

43. **The world is still lacking in the development of bio-fertilizers that will totally substitute synthetic fertilizers, bio-pesticides and bio-herbicides that can substitute synthetic pesticides and herbicides...In such situation how we could balance between food requirement and sustainable agriculture?**

There is no one-size-fits-all solution. Biofertilizers have been proven to be very successful in certain crops, however, they can be highly specific and therefore do not work everywhere on all crops. Not all crops can prosper with the use of biofertilizers because of the diversity of crops, soils, climatic conditions, and expected yields. Then, how can the balance between food production and sustainable agriculture be found when a growing population requires to maintain very high yields, especially in the case of basic grains? This can be accomplished through the sustainable use of synthetic fertilizers and innovative technologies. Sustainability and synthetic fertilizers are not mutually exclusive concepts.

The design and implementation of programs to recommend appropriate rates, placement, timing and source of fertilizers, can significantly reduce environmental damage, making their use sustainable. In this sense, the International Code of Conduct for the Sustainable Use and Management of Fertilizers is a support for moving towards sustainability with fertilization practices. The balance can also be found through technological innovations. The use of fertilizers with nitrification inhibitors or coated fertilizers can reduce the adverse effects on the environment and damage to human health. The use of nanotechnology and precision agriculture also allows the release of fertilizers to be synchronized with the nutrient demand of crops. It is not necessary to completely replace the use of synthetic fertilizers, particularly with the emergence of new technologies. The ideal is the combination of several strategies to develop solutions suited to different types of production systems, climates, topographies, and soils.

44. **Is there an easy way to measure carbon in the field and easy for small farmers to carry out?**

The Soil Testing Methods Manual (STMM) - in the framework of the Soil Doctors Global Program - allows determining SOC indirectly through the active / labile carbon method (page 62).

45. **Understanding carbon mineralization rates in agricultural soils is very important when trying to sequester more carbon in soil. There are farmer friendly easy tools that we can effectively use in field scale to study carbon mineralization.**

The Soil Testing Methods Manual (STMM) was developed as a list of methods and equipment needed to assess the parameters considered critical to soil health.

46. **Are you considering the soil recarbonization program in the context of urban/peri urban, natural based solutions context?**

RECSOIL will focus on agricultural soils. If there are reasonable experiences with urban/peri-urban agriculture, we will explore whether these can also be taken into account.

47. **What do you think of the CO and N (soil) data deriving from historical methods, such as Walkely and Black and Kjeldahl, compared to the values obtained with the use of automatic analysers (CNS analyser, Skalar)? It seems to me that the analysers give higher nitrogen values than with the Kjeldahl and consequently lower C / N ratios are obtained. In cultivated soils of the Po Valley (N-Italy) I find C / N values even around 8. In short, with the analysers I no longer find the C / N values that I previously obtained.**

C/N ratios calculated from Walkley & Black (W&B) OC and Kjedahl N might be different from that calculated using DUMAS TOC and TN. There are a number of contributing factors:

- W&B OC does not measure the same pool of Carbon as Dumas Total OC. W&B OC can be between 70 and 90 % of the TOC depending on soil type and carbon fraction present. It is also important to ensure that the Dumas TOC is the TOC and not the total Carbon, which may have inflated values due to more recalcitrant Carbon fractions (e.g. charcoals, woods, carbonates etc.). The C/N ratio may be elevated in some soils.
  Still, C concentration results given by the W&B rapid dichromate oxidation method are generally lower than those obtained by the dry combustion reference methods. To overcome the problem of incomplete C recovery, which leads to the underestimation of C concentrations by the Walkley-Black method, the analytical results of this technique are corrected by a factor commonly reported as 1.30 when no external heat is applied.
- Kjeldahl N is not the total N obtained with the Dumas method. Kjeldahl N will not include N associated with N-O bonds such as NO3 which the Dumas N method will most often measure by giving a higher value. The C/N ratio may therefore be lower in some soils.
  Still, in organic soils or soils with high organic matter contents, the results of N concentration obtained through the Kjeldahl method are generally lower than the results of dry combustion. For mineral soils or soils with low organic matter contents, results have been comparable between the two methods.
- Due to the relatively lower levels of N to C, differences associated with the methods can have a significant effect on the C/N calculation.

Unfortunately, the question is not detailed enough to provide a more precise answer.
In conclusion, uncertainty ("dispersion") needs to be taken into account before comparing C/N ratios obtained with different methods. Indeed, in case of high uncertainty, results obtained using different analytical methods will not be significantly different.

48. Don't you see a danger that certificates lead to a kind of Greenwashing and promote unsustainable ways of Carbon Sequestration?

This is always a danger when designing a credit or ETS scheme. The GSOC-MRV Protocol has been drafted with this in mind and will be changed to address any perceived abuses. FAO and the GSP are committed to respecting all aspects of FAO's Mandate, which precludes promoting or permitting unsustainable practices.

49. What are the new digital/innovative technologies available for young farmers to adopt SSM?

One example of this is the Digital Agriculture of FAO.

50. What are the constraints of regenerative agriculture practice and soil health practices?

We can think of three main categories of constraints:

- Social: Like any other movement, there is always resistance to the implementation of new practices. Regenerative agriculture and soil health approaches can be considered as innovations, and these require time to fully enter the common language.

- Economic: The transition to new approaches regenerative agriculture, or soil health approaches is a long process (that might take some years). In the meantime, farmers must ensure the survival of their activities/businesses and therefore try to reduce the risk of adapting new practices. That is why we often talk about farm profitability rather than income.
- Lack of support and compensation programmes for farmers: Governmental and para-governmental institutions need to invest more in these transition processes. Farmers need to be trained not only in practices, but also in risk management and planning.

There is also much work to be done to compensate sustainably managed farms, either through the quantification of ecological services or the recognition of their products. RECSOIL will act in this direction by providing economic support to sustainably managed farms.

51. **What is linkage to SOC sequestration and RECSOIL to the "demand" side for resilient, sustainable food systems? Idea - Can we think about "RECSOIL certified products" with labelling? If demand is stimulated, this could fortify the anticipated financial incentives for farmers to adopt better practices.**

Under the RECSOIL Programme, the multiple benefits of carbon sequestration will be measured through the Voluntary Guidelines for Sustainable Soil Management and the Protocol for the Assessment of Sustainable Soil Management, which will determine, among others, productivity, biological activity and water availability. A label of compliance will be given as part of the VGSSM to prove the multiple benefits achieved.

52. **Please let us know how farmers and Farmer Producer Organizations in India can apply for this partnership, it could be a huge game changer in India where farmers are usually very keen to adopt (because of their traditional wisdom) but worried about the economic trade-offs especially the yield drop in initial years.**

RECSOIL will be rolled out in 2021. Specific information and calls will be launched at the beginning of next year, so this will be an opportunity for Indian farmers to respond to the call.

53. **I am interested in carbon and soil recovery under plantation forest in humid climate. Due to repeated cycles of harvest and planting of mostly Acacia, what is best practical ways to promote litter decomposition later improve soil nutrient?**

We invite you to consult the very detailed review [https://link.springer.com/article/10.1007/s40974-017-0064-9] of Krishna and Mohan (2017) on the topic of litter decomposition in forests ecosystems. The paper first highlights that litter decomposition is highly dependent on climatic variations, which is the lead influencing factor at a large geographical scale. In a second time, trees diversity has a role to play in litter decomposition as follows:

- The leaves of coniferous trees decay more slowly than those of deciduous trees, because broad-leaved litter covers more potassium and phosphorus, less lignin and nearly always less ether-soluble sections.
- The decomposition of teak litter appears more rapidly than that of Acacia Arabica litter; leaf litter vanishes much sooner than twigs and branches and litter under forest canopy is softer and disappears more quickly than leaves exposed to sunlight, although deviations in the rate of leaf litter decomposition of the same plants during different seasons at different locations might be observed.

- The rate of decomposition is high in species with extreme ash and nitrogen contents and the lowest C/N ratios and lignin contents. Species showing average ash, nitrogen and lignin contents and a normal C/N ratio appear to decay at a transitional rate.

54. **There is GAP labelling (good agricultural practices) already there in field (FAO involved). Can we include RECSOIL in that existing system to improve it than introducing another label?**

Except for the label of compliance proposed by the RECSOIL Programme, no label has been developed by FAO so far.

55. **What would be a better way to pay to farmers for sequestrating carbon in their soils? Percentage C added or ton C added per ha basis? Many carbon credits program advocate percentage basis and I am a bit reluctant to accepting it.**

All carbon accounting is done in tons. Therefore, the RECSOIL Programme will follow current and future carbon markets regulations and the IPCC Guidelines. All these documents are based on the additionally concept.

56. **What happen with farmers who are already implementing SOC sequestration measurements? Can they participate on RECSOIL?**

Yes, they can participate. They will need to comply with the same steps all other farmers do.

57. **Can FAO organize a webinar giving information in detail on measurement of soil carbon sequestration and carbon trading/carbon market?**

Yes, of course, we will do it soon.

58. **California also provide incentives in the form of grants to growers to reduce greenhouse gases and sequester carbon and promote soil health. Assuming all growers sequester carbon in their practices, how much can they remove compared to manufacturing and industry?**

A series of publications compares sequestration potential and industrial emissions. The IPCC Special Report on 1.5ºC could be a first step in finding an academic peer reviewed answer to this question. However, it should be considered that the mitigation potential of agriculture-based solutions is moderate, although highly effective in terms of time residence in soils.

59. **How to make sure farmers who already have implemented good practices are not left behind as the potential for SOC restoration will clearly be greater in those farms that haven't?**

The RECSOIL Programme is designed to include all farmers.

60. **When will the label/certification be given to farmers? After 8 years of monitoring if SOC has increased? In this case, how will the investments/costs of early years be covered? Any incentive for farmers?**

The RECSOIL Sustainable Soil Management Seal is given to farmers after they have passed the Induction Process and become RECSOIL Farmer Members. The final step in the Induction Process is the approval of authorized technical and financial support on a project-by-project basis (one farmer or one group of farmers). This technical and financial support will allow farmers to apply the necessary sustainable soil management practices.

61. **Are there policies by RECSOIL in order to drive SOC policy in European Union?**

RECSOIL has not yet been rolled out, but we foresee that the EU marketplace will be a target market for the RECSOIL programme, especially in the light of the EU's commitment on climate and agricultural issues alongside the existing regulatory infrastructure to support programmes such as RECSOIL.

62. **Agriculture needs to close an 11-gigaton greenhouse gas (GHG) gap between expected emissions in 2050 and those needed to hold global warming below 2 degrees C. How much of this amount will result from RECSOIL?**

RECSOIL does not have a goal *per se*, according to recent studies the global technical potential of SOC sequestration is 1.45–3.44 Gt C / year. Of which 1.1–2.5 Gt C / year, correspond to arable, pastures, permanent crops and urban lands. RECSOIL focuses on the technical potential of agricultural and degraded soils. On the other hand, it is important to mention that the SOC sequestration capacity depends on several factors such as soil type, depth, clay content, landscape position, nutrient reserves, plant available water holding capacity, and SOC stock baselines.

63. **Are there any suggestions for a young researcher such as myself to work on SOC considering lack of resources?**

We recommend that you to apply to a number of research funding opportunities in case you want to pursue this topic further. It is very important to focus your research on local issues and to connect with international research groups.

64. **Why waste management in particular food waste management has not been highlighted as one of the best ways to increase soil carbon when composted, especially when the current management practices are so unsustainable.**

Food waste composting management has indeed been much studied in the last years, and appears to be a major lever to reduce the negative impacts of food waste (FAO estimates that 14% of the world's food is lost post-harvest up to (but not including) the retail level). However, further research is still needed and concerns remain regarding the composition of these composts, which might be highly variable. In addition, composts made from food waste may sometimes contain residues of non-biodegradable materials (e.g. plastics), which reduce the purity of the composts (see also Cerda et al., 2018). Studies are currently being carried out to optimize the potential of food wastes, for example by converting them into biochar (see Waqas et al., 2018). Biowaste compost effects on carbon sequestration can be substantial (more than 3 $tC.ha^{-1}.y^{-1}$, Baiano and Morra, 2017) or neutral (between 0 to 1 $tC.ha^{-1}.y^{-1}$, Yang et al., 2014), depending mainly on the composition of the compost and the context of application.

65. **How does RECSOIL dress the problem that many farmers do not own the land, and some are afraid that if they improve the soil, the value of land will increase and they will lose the land to the owner?**

This aspect will be analysed on a case-by-case basis. If alternative solutions are possible, they will be proposed to these farmers.

66. Do you think Agriculture without chemicals is possible? Food and health are not compatible with chemicals! How is this possible? **http://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/es/**

Agriculture without the use of chemicals is possible through the implementation of sustainable management practices, ensuring natural nutrients balance processes, such as for example manure application, crop rotation, intercropping, cover crops, maintaining of soil biodiversity, and integrated pest management.

67. How can one motivate less educated farmers to help them understand the importance of not burning fields in India?

Slash-and-burn and other practices that involve burning agricultural fields are common in many parts of the world, however, educating farmers about the negative impacts that this practice can cause can be a good start to ending the practice. This can be done through extension services or programmes to train and empower farmers. Burning organic soil residues has visible negative effects in the soil that can be observed with farmers, with the support of the Soil Doctors Global Programme infographics and materials. The first observations are the loss of soil structure and the loss of meso and macrofauna. In soils that have been repeatedly burned for several years, soil compaction and leaching of fine particles can also be observed, disaggregated by combustion.

68. If farmers' willingness is there then, why farmers are using excessive pesticides and fertilisers and degrading the soil?

FAO works closely with governments, the private sector and farmers' associations to find the best ways to bring scientific knowledge together in effective regulation. To this end, the International Code of Conduct for the Sustainable Use and Management of Fertilizers and the International Code of Conduct on Pesticide Management have been developed, proposing actions for all stakeholders. The next step is to invest in building the capacity of all these stakeholders to implement the sustainable measures identified in both Codes. Ensuring that governments, the private sector and farmers advocate for sustainable management practices is only possible if they have all the information and can make informed decisions. Recognition of the economic value of soils and the ecosystem services they provide is also a tool for ensuring their proper and sustainable management in the long-term, compared to the short-term gains that lead to soil degradation. More specifically, as part of the Soil Doctors Global Programme, FAO has a section on soil pollution prevention.

69. Do the potentials for carbon sequestration presented today include the predicted impact of climate change on soil organic matter?

Please consult:

Lal, R. 2018. Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in agroecosystems. Global Change Biology, 1–17.

Lal, R., Smith, P., Jungkunst, H.F., Mitsch, W.J., Lehmann, J., Ramachandran-Nair, P.K., McBratney, A. B., de Moraes-Sá, J. C., Schneider, J., Zinn, Y.L., Skorupa, A., Zhang, H.L., Minasny, B., Srinivasrao, C., & Ravindranat, N. H. 2018. The carbon sequestration potential of terrestrial ecosystems. Journal of Soil and Water Conservation, 76 (6).

70. How about 4per 1000 initiative a global level?

The GSP collaborates with the Scientific and Technical Committee of the 4 per 1000 initiative to contribute to a better understanding of SOC at the global level.
The Scientific and Technical Committee of the 4 per 1000 initiative is part of the scientific board of different documents that are about to be published, such as:

- Best soil management practices for SOC maintenance and sequestration: a technical manual.
- GSOC-MRV Protocol: A Protocol for Measurement, Reporting, Verification and Monitoring of Soil Organic Carbon in Agricultural Landscapes.

71. When will GSP release the document on RECSOIL which was made available for comments?

The RECSOIL document is available on the GSP webpage, we are now preparing a new document with details about the market and it will be available on the GSP webpage.

72. What should be short, medium and long-term strategies of C-sequestration for small and marginal farmers in South-east Asia? Any systematic studies and implementation anywhere?

Please consult the following links:

- https://www.nature.com/articles/s41467-019-09646-4
- https://link.springer.com/article/10.1007/s10668-019-00414-4
- http://www.fao.org/forestry/23345-0fe9d497a6fe0cd299cb5b9186f66887a.pdf
- https://www.tandfonline.com/doi/abs/10.1080/17565529.2018.1442798

73. At which stage will the label/certification be given to farmers? After 8 years of monitoring if SOC has increased (in this case, how will the investments/costs of early years be covered? Any incentive for farmers?) or at the beginning of the process (and in this case with the risk of no SOC increase in the end)?

The RECSOIL Sustainable Soil Management Seal is given to farmers after they have passed the Induction Process and become RECSOIL Farmer Members. The final step in the Induction Process is the approval of authorized technical and financial support on a project-by-project basis (one farmer or one group of farmers). This technical and financial support will allow farmers to apply the necessary sustainable soil management practices.

74. If I may, curious whether the "Carbon Farming Initiative" by the European Union is linked to the Common Agricultural Policy?

The UE has announced that the EU Carbon Farming Initiative will be linked to the CAP. See:
https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/events/documents/carbon-farming-schemes-roundtable-background_en.pdf

75. Experiences with positive effects on SOC and yields and length of field productivity by phasing out the burning phase in subsistence farming systems? Specially to convince farmers.

Please consult the following links regarding the Quesungual System:
http://www.fao.org/soils-2015/news/news-detail/en/c/318676/
http://www.fao.org/3/a-at763s.pdf
http://www.fao.org/3/i9076es/I9076ES.pdf

Please consult the following references:

- **Mahajan, A., & Gupta, R.** 2009. Soil-Related Constraints in the Rice and Wheat Production. In: Mahajan A., Gupta R.D. (eds) Integrated Nutrient Management (INM) in a Sustainable Rice—Wheat Cropping System. Springer, Dordrecht
- **Raza, W., Yousaf, S., Niaz, A., Rasheed, M.K. & Hussain, I.** 2005. Subsoil compaction effects on soil properties, nutrient uptake and yield of maize fodder (Zea mays L.). Pakistan Journal of Botany 37(4): 933-940.
- **Sharma, P.K & Mishra, B.** 2001. Effect of Burning Rice and Wheat Crop Residues: Loss of N, P, K and S from Soil and Changes in the Nutrient Availability. Journal of the Indian Society of Soil Science 49(3) 425- 429.
- **Kumar, A., Kushwaha, K.K., Singh, S., Shivay, Y.S., Meena, M.C. & Nain, L.** 2019. Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic plains. Environmental Technology and Innovation. 16(100469). ent uptake and yield of maize fodder (Zea mays L.). Pakistan Journal of Botany 37(4): 933-940.

76. **If you can describe the current state of soil carbon sequestration in Mediterranean forests.**

The GSP is currently developing the Global Soil Organic Carbon Sequestration Potential Map (GSOC seq) for agricultural soil. Regarding forest soils please consult to the following studies:

- https://link.springer.com/chapter/10.1007/978-1-4020-8343-3_13
- https://link.springer.com/article/10.1007%2Fs11056-006-9011-x
- https://link.springer.com/article/10.1007/s10342-007-0198-y#article-info

77. **Why are we always inventing the wheel again? Why don't we build on the work, FAO and others in the world have done over the past 23 years on Conservation Agriculture?**

The RECSOIL Programme builds on FAO's work in conservation agriculture and aligns it with global climate, biodiversity and similar goals, while pursuing FAO's broad Mandate. It includes technical and financial support to farmers and resources mobilization from carbon markets and carbon pricing initiatives on a global scale. All of this to support sustainable soil management practices in a programme that is inclusive and mutually supportive over time. The programme seeks to solve the problems facing humanity today and in the future. It is based on the best knowledge and experiences gathered by FAO and many other organizations around the world. On the other hand, we are not inventing the wheel again, but the practices recommended by are based on the Voluntary Guidelines for Sustainable Soil Management published by FAO in 2016. It is the same wheel with three others that help the car move forward.

To Professor Rattan Lal

78. **Amount of C possible to sequester within soils being used for agriculture is relatively small compared to removing land from agriculture or avoiding deforestation or wetland drainage. Great for soil health but limited for climate change mitigation. Do the speakers agree?**

No, I disagree. With the adoption of recommended management practices, which reduce losses of nutrient and water by erosion and leaching /volatilization, also increase use efficiency of inputs, and thus avoid emissions, the net effect of climate smart agriculture is a negative emission. The net sequestration may be as high as 1 Mg C/ha.yr in the best-case scenario. Furthermore, this approach makes it possible to produce more with less and saves land and water for nature. This is a land-saving option that avoids deforestation and drainage of peatlands.

79. **How much soil carbon should be maintained in tropical and subtropical soils?**

There is no one specific optimum level for SOC. In general, an optimum range of SOC is 1.5 to 2.5% in the root zone (top 20 cm) for soils in the temperate zone and 1.0 to 1.5 % for soils in the tropics. Most cropland soils in the tropics, especially those prone to erosion, are severely depleted of their original SOC stock. Restoring carbon in these soils will increase production.

5. The carbon dynamics are different in tropical soils and seasonal areas, is the same measurement strategy used or does it change?

The measurement strategy or technique is different. However, the soil management strategy may differ depending on the climate, soil, farming system and farm size etc.

80. **A question for Professor Lal: Your recommendation that SOC storage requires sampling to 1m every 1-5 years with accounting for soil bulk density. Can this be done cost-effectively today?**

Yes, there are modern innovations that are cost effective. Remote sensing techniques, based on terrain characteristics, are also being used and are economical.

81. **What is the best method to evaluate the carbon content in dry soil (arid rangeland) with more than 90% of sand?**

I am not sure how important the sand content is, I am sure that the soil pH has to be known. If the soil pH is above seven, it means that the soil contains carbonates. Thus, the total carbon determined by the dry composition method must be corrected for inorganic carbon content to obtain credible data on soil organic carbon stock.

82. **Much enjoying your excellent presentation. I agree that soil erosion moves a massive amount of soil carbon. But would not some of eroded soil actually end up protected from decomposition, or buried to a depth where decomposition is slower?**

Thank you for your kind words. Yes, it is absolutely correct that some of the organic carbon transported by erosion can be buried and thus protected from decomposition, However, a large part of the carbon is redistributed over the landscape and is prone to decomposition under both aerobic and anaerobic conditions. In the latter case, the emission of methane and nitrous oxide causes serious problems. Furthermore, the removal of soil organic carbon from upland soils decreases productivity on site, leading to a severe decline in biomass production and a further reduction in the ecosystem's carbon stock. Overall, accelerated soil erosion is a major source of GHG emissions.

83. **What should be done to reverse the desertification in the shortest period of time?**

Conservation of water in the root zone, afforestation of steep lands, and adoption of practices that will restore the vegetation cover is the best strategy. The area where vegetation is established must be protected from grazing.

84. **A question to professors Lal and Smith, may the application of pyroligneous acid a way to improve the stable SOC in deeper soil layers?**

Yes, the application of biochar can increase carbon stock. Having biomass in dry climates to produce biochar for application at a high rate can be a challenge. More than 40% of the world's land area is dry and the proportion of dryland could reach 50% by 2100. These areas have low productivity. Thus, biomass can be a scarce resource in these regions.

85. **According to some studies, when the temperature exceeds 2 °C above the 1990 level, the reserves of the terrestrial carbon biosphere will be saturated, in particular in the Amazonian forest which can lose their carbon and start transition to savana biome. Being close to this threshold, how much do you think this affects the application of soil recarbonization?**

Professor Smith and I have prepared a global estimate of the carbon sink capacity of the terrestrial biosphere (soil, forest, including all degraded lands) between 2020 and 2100. The potential (maximum possible) is about 330 Gt for the next 80 years. This would be equivalent to a CO_2 withdrawal of 150 ppm. This is not small. It will also have numerous co-benefits.

86. **Can I receive some literature references about the SOC threshold to which we can obtain good crop Yields? He indicated a range of 2.5 - 3% as sufficient.**

The critical threshold level for SOC in the root zone is about 1.5 to 2.5 % (or 3 to 5 % of soil organic matter) in temperate soils, and 1.0 to 1.4 % (2.0 to 3.0 % of soil organic matter content) in tropical ecosystems.

87. **How can we measure all carbon pool with different depth and minimum how many years take for passive carbon pool build up in soil?**

It can take 3 to 5 years from traditional to recommended practices to see a measurable change in SOC content. If the recommended practices are maintained forever, the build-up of SOC in the profile to 1-m depth may continue for 50 years. There are many new techniques for assessing the SOC stock at deeper depths. One of them is called INS (inelastic neutron scattering). Modelling (Roth C, EPIC, and Century etc.) is rapid and cost-effective.

88. **You mention slow decomposition of straw. Is there possibility of nitrogen (N) capture during the decomposition of straw and/or stover? How do you address it?**

A high C:N ratio can reduce the rate of decomposition and also immobilize N. Adding legumes to the rotation or supplying other sources of N (compost, green manure) can increase the rate of decomposition.

89. **What's your recommendation to increase C sequestration in slope land tea plantation?**

For sloping croplands, the adoption of conservation tillage without plowing and leaving the crop residues, along with agro forestry and cover cropping can create a positive soil/ecosystem carbon budget. Effective soil erosion control is extremely important. Erosion is a thief of soil organic carbon.

90. **Do you recommend the replacement of (biodegradable) mulching plastics by organic products such as bark?**

Any vegetative mulch is good protection. Even gravel mulch is good in dry climates for rainfall of 300 to 400mm /yr. Plastic mulch is good but it is polluting. Biodegradable plastic sheet is a good choice. In-situ much from retention of crop residues is the best option.

To Professor Pete Smith

91. **Why there is NOT only one procedure for measuring the stability of the organic waste and potential organic amendments (e.g. manure, slurry, sludge, digestate, and compost)? As far as I know the stability is measured in different way depending on the type of waste.**

The stability of all amendments can be assessed through the same controlled decomposition experiments – it does not have to be measured in a different way for different organic amendments.

92. **Amount of C possible to sequester within soils being used for agriculture is relatively small compared to removing land from agriculture or avoiding deforestation or wetland drainage. Great for soil health but limited for climate change mitigation. Do the speakers agree?**

Avoiding deforestation and avoiding wetland drainage are important, but is not an "either/or" question – we can and should avoid deforestation and avoid wetland drainage on land where that is a key threat and enhance soil carbon stocks, where possible, in agriculture (especially croplands). There is a significant technical and economic potential in these lands. There are some barriers, of course, but we must do our best to overcome them. As the question points out, this is good for soil health too.

93. **Which Biochar is suitable given biochar can be generated from different materials? Also, which soils does it efficiently work?**

There are many different feedstocks for biochar – suitability depends on availability and environmental impacts. Some waste materials are not suitable due to contamination (e.g. organic pollutants or heavy metals). Biochar works well is most soils – but probably works best is very organic matter-depleted soils.

94. **Where will vast amount of OM come from to make biochar for use on large scale?**

In the first instance, waste streams could be used (residues, forest thinnings etc.), but if biochar were to be scaled-up greatly, dedicated biomass plantations would be needed – with all the implications that go with additional land use.

95. **Experiences in Belgium with biochar show it as not feasible: the production is very CO2 intensive; it does not contribute to the sponge effect of the soil and s rarely available. What is your idea about that?**

There are varying experiences with biochar, good and bad. There are some good reviews available, which take into account a variety of studies. A recent one is here: https://link.springer.com/article/10.1007/s42452-019-0172-6

96. **15. Is biochar really a solution? Is there is risk that nutrients quand be less available with biochar amendment of soils?**

This is the subject of research. A recent review is here:
https://link.springer.com/article/10.1007/s42452-019-0172-6

97. **19. A question to professors Lal and Smith, may the application of pyroligneous acid a way to improve the stable SOC in deeper soil layers?**

I have no expertise on this so i cannot provide a response.

98. **20. What are the costs associated with biochar production?**

Costs were reviewed here: https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.13178
I EXTRACT THIS TEXT: "Estimates for costs of production to application of biochar (assuming UK conditions) are about −830 to around 1200 $ tCeq. −1 (converted from GB£ tCO2-eq. −1 values in Shackley et al., 2011). The mean of this range is 185 $ tCeq. −1 A tighter cost range is derived from values in Meyer et al. (2011), using costs of 51 to 386 $ tbiochar−1 (for yard waste and retort charcoal, respectively), giving cost ranges of 54–406 $ tCeq. −1 if 95% C content from slow pyrolysis is assumed, or 100–757 $ tCeq. −1 if 51% C content from torrefaction is assumed. The mean of these ranges are ~230 and 430 $ tCeq. −1, respectively. There may be economic benefits from biochar application that offset some of these costs (Dickinson et al., 2014), but the benefits differ by region."

99. **Is there any country where biochar use is in regular practice by the farmers current slide showing clearly the principles of Conservation Agriculture, apparently the solution to sequester carbon at large scale and cost-efficient? But I did miss the mention of the principles and the name of Conservation Agriculture.**

It is certainly practiced in places, but not whole countries. I did not mention conservation agriculture by name – though many of the practices that constitute conservation agriculture have been shown to increase soil c.

100. **Is there any country where biochar use is in regular practice by the farmers? Is there long-term experiment on biochar studying different tangible and non-tangible benefits.**

Experiments reviewed in
https://www.sciencedirect.com/science/article/pii/S0167880911003197?via%3Dihub

101. **Do you think we should change the global narrative to shift more to indicating the economic SOC sequestration potential in order to create more achievable targets and values? Or at least indicate the economic SOC sequestration potential along with the technical potential? In a way it is similar to requiring uncertainty and accuracy values for soil maps to understand how realistic or achievable estimates are. 2) Do you find that the economic SOC sequestration potential is as context specific as technical SOC sequestration potential?**

I do think it is useful to quote economic potentials (at a given carbon price) and i always quote them when I can. It does not reflect uncertainty – only cost – and it does not reflect non-economic barriers. Non-economic barriers also need to be considered to estimate what is achievable / realistic, so this requires more than merely reporting the economic potential. 2) Depends on carbon price for the economic potential. Globally, at 20 USD/tCO_2e, it is about half of the technical potential.

102. **Dr. Smith discussed about using Remote Sensing for mapping SOC. I don't see any authentic proven study which can be adopted on operational level. In India DOS has made effort to map SOC at national level using RS.**

Remote sensing can detect land cover and land use, which can be used to verify activity data (*i.e.,* to check that a practice that is claimed is actually happening).

103. **It seems to build up organic carbon (recarbonization) is difficult in the wet tropical red soils. How we can increase and stabilize carbon sequestration in such red wet tropical soil?**

I do not have specific expertise of tropical red soils.

104. **Is it possible to determine carbon holding capacity of tropical soils?**

I think it is possible – is there any reason why it cannot be measured on tropical soils?

105. **In drylands of West Africa where crop-livestock integration prevails, soils are mainly of a coarse texture and SOC in cultivated situations are very low. OC stocks rely on organic inputs that can be applied to soil, but the resources are not enough available to fully cover all needs, for soil amendment and other uses as animal fodder. Is Biochar use in dryland thus questionable if derived from local organic resources?**

Yes – finding the feedstock to produce the biochar could be the biggest challenge.

Comments

1. In my opinion, GSP is less involved in research or funding of it but rather relies on localized data generated by local scientist for which it has little control. It has to be noted that the most critically carbon deficient soils are those of in the drier tropics, especially the direr sub-Saharan. There is at present to my knowledge no deliberate attempt to put much carbon back into those degraded soils apart from insufficient manuring practice by poor resourced farmers. Statistics aside, there must be serious research to look into options that will put back the much-desired carbon into the soils. That must include deliberate funding from institutions such as FAO or the GSP. In addition to the options just mentioned by Prof. Lal, I would want to propose options such as carbon material (e.g. biochar) incorporation into or fortification of inorganic fertilizers which is a very popular and highly in demand resource among farmers in the dry regions.
2. My observation as a farmer. Traditionally it was taught that chemistry and physics govern soil fertility. Soil fertility lay in its cation exchange capacity – its capacity to hold positively charged ions, essential nutrient like potassium (K+) and calcium (Ca2+) loosely enough for soil water to take them up. This isn't wrong, there is just more to the story. Standard soil chemistry tests only measure the soluble fraction of what is in the soil. Nutrients tightly held in soil organic matter don't show up in conventional soil tests, neither do all the nutrients locked up in slow-to-dissolve minerals. Soil chemistry lab reports are missing something big: the potential for soil life to convert nutrients from mineral soil and organic matter, into soluble forms plants can use. The plant microbe associations have served nutrient cycling well since the beginning of time, only in the last couple of decades has the science of measuring their relationship with plants come to light.

3. About Carbon market. The neocapitalistic (and neoliberal) model we adopted in the last couple decades is clearly the source of many of the issues we are now trying to address today (over exploitation of natural resources, power imbalance in land management, land capture, agribusiness corporates, the will to make as much money as possible, etc). That model does not work for the greater good, not because of the people in charge, but because of the underlying values out of which this system emerges. Carbon market is still the same mindset, it is still in the same line of thinking (commoditization of everything). That mindset led us to the current crisis, isn't thinking that it will take us away from slightly unrealistic.
4. GSP has published some wonderful infographics for extension on SOC, Soil Biodiversity. Since we have the farmers understanding HINDI and the infographics are in English, Could you help me by sharing through your team the graphic files, so that I can translate the language to Hindi, which I wish to use to take to millions of the farmers of India.
5. I think Farmers need incentives to be able to be real vehicle for change. The main incentive would be to have security of land tenure. They need to have formal land right. For this to happen, political will and commitment is key to make it happen.
6. A change after 4 years could be in the order of 1% in SOC stock. This is very difficult to detect. With CIRCASA project we are developing an alternative approach based on the balance of carbon also with remote sensing.
7. The development and climate Alliance of the German Federal Ministry is a good platform to enable financial support from the private sector. RECSOIL should join us
8. We need to leverage a paradigm shift that provide consistent and continuous incentives to farmers, less pilot, more scale up on existing trials.
9. We need to understand that the soil C balance in terrestrial ecosystems is simple: as follows: Soil Organic C = Photosynthesis C input - [(Plants respiration C + Soil respiration C) + (Erosion C losses + leached C)] output (see details in Supplementary Information, section xx). Thus, the C accumulation in the soil will occur when the biomass-C input is greater than the C output.
10. PAH /poly aromatic carbon content and its impact on soil environmental health has to be established.
11. Agriculture have been successfully changing and adapting to cover human needs and demands. Now it is also a time for changes, but it requires strong support of society and governments.
12. No mention of plant liquid carbon production, exudates, soil food web, microbial necromass carbon, rhizophagy etc. we must do better in these talks.
13. Microbial immobilization of N with straw application is why we can't add raw carbon to soils, without some loss in productivity… However, it seems the soil microbial biomass does not recognize biochar carbon as a microbial carbon source and therefore does not cause this type of immobilization meaning we can add much higher amounts of carbon with positive or neutral effects on crop production.

Annex 2 | Agenda, presentations and recording

Agenda

15:00 - 15:15 | **OPENING REMARKS**
Dr Qu Dongyu, FAO Director-General
Mr Ibrahim Thiaw, Executive Secretary, United Nations Convention to Combat Desertification
H.E. Carlos Manuel Rodriguez, Minister of Environment and Energy of Costa Rica

15:15 - 15:25 | Status and challenges of global soil organic carbon sequestration – *Prof. Rattan Lal*, Distinguished University Professor of Soil Science and Director of the Carbon Management and Sequestration Center, The Ohio State University, Ohio, USA

15:25 - 15:35 | Is soil organic carbon sequestration really feasible? How to scale it up? *Prof. Pete Smith*, Professor of Soils and Global Change, Aberdeen University and Science Director of Scotland's ClimateXChange

15:35 - 15:45 | Soil organic carbon sequestration: experience from the ground, *Ms Maria Beatriz Giraudo,*Farmer from Argentina

15:45 - 15:55 | Unlocking the potential of soil organic carbon: RECSOIL, *Ms Rosa Cuevas/Mr Ronald Vargas, FAO*

15:55 - 16:25 | PANEL SESSION - Moving the SOC agenda into action:
Ms Arianna Giuliodori, Secretary General, World Farmers Association
Mr Eric Fernandes, Global Lead, Technology-Innovation-Climate Smart Agriculture, World Bank Group
Ms Christine Mueller, Policy officer, DG Clima, European Commission
Mr Barney Debnam, Strategy Lead Agriculture at Microsoft

16:25 - 16:30 | **CONCLUSION**, *Ms Maria Helena Semedo*, Deputy Director General, Climate and Natural Resources, FAO

Moderator: *Mr Eduardo Mansur*, Director, Land and Water Division, FAO

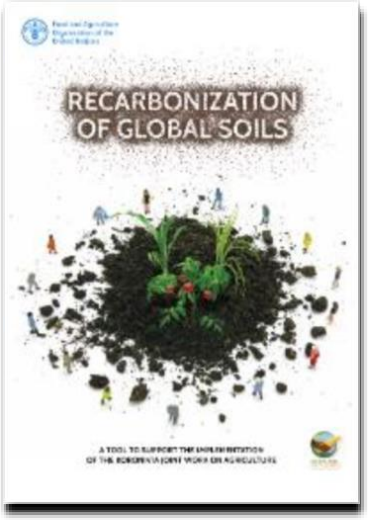
Presentations

- **Status and challenges of global soil organic carbon sequestration** – *Professor Rattan Lal*
- **Is soil organic carbon sequestration really feasible? How to scale it up?** – *Professor Pete Smith*
- **Soil organic carbon sequestration: experience from the ground** – *Ms Maria Beatriz Giraudo*
- **Unlocking the potential of soil organic carbon: RECSOIL** – *Ms Rosa Cuevas/Mr Ronald Vargas, FAO*

Meeting recording

- LINK

Publication



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