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Thank you for this introduction and good afternoon. Good afternoon. It's a great honor to be here and it's a pleasure in this amazing event.

So, yes, I come from France and actually you can see I'm work in Grignon. Grignon is a small village. It's in the far suburbs of Paris, in the suburbs of Versailles, where I live. So different settings, different environment, much less land, much smaller country. And I work in soil organic matter and what I would like to talk to you about this afternoon is organic matter as a solution to global challenges. And I hope to introduce you to this topic to make you understand better, maybe, and to convince you to go forward.

So global challenges. Global challenges, the more important one is probably food security. You all know about it so I'm not going to detail what are the global challenges but it's also it's interlinked with water security, with climate change, with biodiversity, protection, health issues, energy sustainability and at the crossroads of all, at the nexus of all these challenges is soil security.

Why soil security? Because soils are threatened. It was said this morning by David Montgomery, the FAO estimates, well, the equivalent of the I-, um, IPCC panel that is the ITBS [sounds like] panel on soils estimates that one-third of world soils are in moderate to severe degradation state. So soils are really in danger.

However, and this is a problem because soils provide many ecosystem services. The first one is probably that soils are where food begins, so it relates to food security.

But soils are also the place of huge biodiversity. They also are allowed to recycle our wastes. They infiltrate, they store and they convey the water. So play a large role in the water cycle. They control erosions. We have heard about erosion this morning. They may control or not erosion.

They can emit greenhouse gases. They can also store carbon. They are major players in the climate issues. I will talk more about it later on. And they are parts of our landscape, of our culture, and they are also where our remnants, the remnants of our activities are held and preserved.

And for all these ecosystems, nearly all of these ecosystem services, so organic matter, a part of soils, plays an important role.

So what is organic matter? The question was raised this morning. And I said it's everything that is living or has been living. Soil organic matter comes from the decomposition of all the biomass inputs to soil so it's mainly made of carbon, half of it, about it, so that's why we often talk from soil carbon, soil organic matter. It's different but there's also nitrates, phosphorus and of course oxygen, etcetera.

So it comes from the decomposition. And this, the composition, releases CO_2, but also releases in some oppor-, in some cases, in some situations, all the greenhouse gases, uh, N_2O and methane. And it also, the decomposition also, when it goes through mineralization, also releases nitrogen and phosphorus. Releases nutrients. And organic matter is all this process. So you start from plant residues, plant pieces but are processed by organic, by microorganisms and [inaudible] essentially microorganisms. And what we often call cumis [sounds like] is basically microbes remnants. Remnants of dead microbes and their productions, their exudates.

So organic matter is a mixture of many different types of molecules, of debris, very small pieces of, and more or less linked to minerals. And these different compounds contribute to the soil ecosystem services. So soil organic matter provides ecosystem services.

The most important, probably, the contribution to soil fertility. Soil organic matter helps to have good soil structure, water infiltration and retention, aeration, good aeration for the roots, so all these helps with penetration, root anchorage, root exploration, but also provision of nutrients by its decomposition or by retention on its charges and also allows for the presence of beneficial organisms, such as we talked about [inaudible] this morning.

And two examples of data on soil fertility, because actually, it's not, although it's very well known that organic matter contributes to all these elementary properties that are part of soil fertility, relating organic matter to yields, soil organic matter content to yields is not that obvious.

One example I took from a paper from China. Two different areas in China, a total of 600 studies, so big meta analyses. You can see here yields expressed as a function of soil organic matter content. Sol organic matter stocks, the amount of soil organic carbon you have in a given layer of soil.

You see that it i-, when you have very sma-, lower, very low contents and stocks of organic matter, definitely the soil organic matter, soil organic carbon content is limiting the yields. It increases as you increase the soil organic carbon stocks. And then it plateaus. It plateaus. That means that other elements, other facts are limiting the yields. Maybe the variety, maybe the climate.

And what I put aside, another graph for you, same paper, and I think it's very important. This is yield variation. What did they do in these studies that they accumulated 600 different studies, and they expressed yield variability over 20 years by comparing yields in different years and, again, expressed as a function of soil organic carbon stocks. And you can see that the yield variability decreases as the soil organic carbon stocks increase. So it gives more resistance of soil and of crops to climatic events, to extreme events. Hence, we may say that soil organic carbon, soil organic matter contribute to food security and contribute to adaptation to climate change.

And this is my paper I was, I happened to be reading 2 weeks ago and comes from this area of the U.S., Soil water holding capacity mitigates downside risks and volatility in U.S. Rainfed Maize. It's time to invest in soil organic matter.

Another issue, climate. This graph might look complicated. It is not that complicated. What you have here are some of the main carbon stocks of our planet. While you have the atmosphere, of course, you have the vegetation, and you have soils. You can see that soils contain three times more carbon than the atmosphere. We have a small pool and a larger pool.

And what is represented also are the flexes. The unknown flexes. These are gigatons of carbon, billions of ton of carbon, big, big numbers. In gray you have put [inaudible] respiration [sounds like], what occurs every year, and in red and green you have the disequilibrium. The disequilibrium we are responsible of, emission of carbon from fossil carbon, deforestation and here deforestation and fires and the continental surfaces and the ocean take up some of that excess carbon that goes to the atmosphere.

Yet, it's in disequilibrium, and you know of course that the concentration of carbon of our, of CO_2 of our atmosphere is continuously increasing. Now if you compare numbers, just ha-, make a very back-of-the-envelope comparison of numbers, you can see that a nominal increase of the totals, all carbon stocks of the planet, would of four per mil, point percent, very, very small increase could, could compensate the emissions due to our fossil fuel, our fossil carbon consumption.

So what is behind and what is behind, what is name, and I will talk about it at the end of my talk, the four per mil initiative is that managing a very small increase of soil carbon stocks worldwide would have a major affect on soil climate, on world climate.

Soil organic matter, soil organic carbon is important for climate change mitigation. And what happened, what was obvious during the COP21 in Paris in 2015, you know that all countries committed to do some changes. And some of the changes, about 25 percent of the reduction of the emissions were related to the land sector, agriculture, forestry. But summing up all the efforts the countries planned to do is not r-, is far from being enough to the trajectory where we want to have.

Here you have the trajectory of business as usual. And here you have the trajectory we would like to have if we want to, to stay below 2 degrees raise in the planet temperature. Now this is detailed in this graph here. And here, in yellow, you have the trajectory, here, with what was negotiated during the Paris agreement. So you see that we are far from 2 degrees abutment. So there's a need, it's not enough, what has been planned is not enough to [inaudible] a 2-degree temperature rise and there's a need to find additional technologies.

Technologies is not high technology. Technologies can be what is called negative emission technologies. It's, for example, storing carbon in soils.

So storing carbons in soils. We have to do it. And it was also discussed, presented this morning by David Montgomery. So the questions, so I tried to introduce, so for ecosystem services, food security, climate change adaptation, climate change mitigation, four good reasons to do it. I have tried to present you the reasons to do it, the why. Now I will talk about how to do it. And then we will see where to do it, limits and barriers, risks, and how to go forward.

And I want to take you through this journey with me. So how to do it. Let's go back to the basics of soil organic matter. So, again, I'm using the same graph I will be using through my talk.

The carbon cycle at the local scale, at the plot scale is that, fairly complex, primary production, you can lose carbon through fires. You have exports. YOu have residues coming back. You can add exogenous organic matter. The composts or other organic matter. You have the organic matter related to cattle, to animals, and all this drives the inputs here, to the organic matter pool, to the soil carbon pool. And then we have outputs, outputs by leaching with the rain are very small in agricultural soils. Main outputs are by degradation and mineralization and erosion. This also was presented this morning.

So increasing stocks is either increasing inputs or decreasing outputs, or both. And this can be done through different ways. Now another thing important to understand how to manage soil organic matter is to recognize the heterogeneity of organic matter. That is, some organic compounds are going to stay for a few weeks, even a few days only in soils while others are going to stay for decades. And a vast majority of these organic compounds are going to stay for decades, centuries, millennia even.

And of course in terms of climate change mitigation, what is more important is the stable, while for soil health, if you want to sustain biodiversity, if you want to provide nutrients, you want the organic matter to turn over, so we want all of that.

And what controls this residence time of organic carbon in soils is a variety of factors, nature of the organic matter, na-, decomposes, the temperature, the water, the aeration, the nutrients, the pH, the soil type, that extends the variability of the organic carbon contents, stocks, all over the world according to the climate, to soil type, geology and to management also.

OK. So increase inputs, decrease outputs. Well, the first way to do it could be to change land use. Indeed, when you look at soil organic carbon stocks, this what is represented here and here in the two figures, as a function of land use, you see big changes.

I took two examples, one in Rwanda, one in France and both show the same and that it would be the same for the U.S. It's that crops, soils under cropping always have much smaller soil organic carbon stocks for a given depth than soils under permanent grassland or permanent, or forests. So the solution could be mass [inaudible] forestation, could be putting everything in grasslands. Except the issue, of course, of livelihood of farmers and the issue, of course, of food security.

So it's very important to preserve the stocks that are in grassland, in the grassland, to preserve the stocks that are under forests. But still how to manage now the stocks under agriculture lane, under cultivate, under cropped land.

So I'll go back again, I will use my cycle at the local level. There are different levers that can be used. For example, increasing primary production. Increasing photosynthesis. Well, we have thi-, we had examples this morning. Cover crops, cover crops between two succeeding crops that bring a lot of ecosystem services.

Also grass, grassing, grassing between orchards, layers of trees and between vine trees here, for example, in Southwest France. Temporary grassland. It makes also a lot of primary production, lots of photosynthesis. Agroforestry. You have all the biomass produced by the trees, in addition to that of the crop. Here is in Togo, for example.

A second lever is to ban fires and this is, of course, tried in many, and forbidden in many countries because this is a net loss of carbon. Although, of course, it was done because it brings benefits in terms of diseases.

A third lever is to try to reincorporate in soils more of the residues and export less. So return the straw [sounds like] as much as possible.

Another lever is to import exogenous organic matter that comes from outside of the plot. For example, manure or compost from the cities and this is a compost pile.

Another lever is managing the cattle through, for example, managing the mowing frequency, managing the grazing frequency, the way the animals occupy the land available.

All this changes the inputs to soil. Now try to manage outputs, to reduce outputs.

Reduce erosion is very important and this can be done through, we also had examples this morning covering the soils with mulch as in conservation agriculture. And also with agroforestry with hedges, like here in South Asia.

And try to reduce biodegradation mineralization. Well, this is what is intended for and what happens so far, to some extent, in no-till systems, where soil is not perturbed frequently.

So you can see different levers. The different levers are different efficiencies in terms of soil organic carbon storage and I will not show you numbers but there are many comparisons that are undertaken that happened on a, are undertaken different areas of the world. And these are important to have quantitative estimates for the reasons [inaudible] on this side of the story, reasons to choose either one of the levers.

Now I would like to focus on two examples to bring you research results. No tillage. No tillage. Well, the ability to increase soil organic carbon stocks under no tillage has been recently reevaluated by a survey of meta analyses. Meta analyses is when it's like the example in China I showed you is when you gather the results of many, many different studies and you treat that like it was your experiment. So you calculate a mean. You calculate a variation and it's very powerful.

And what has been shown, and this is one example of the recent meta analyses is that what do you have here is you have depth here and this is the difference in soil organic carbon stocks to these steps, the different depths between NT's for no tillage, minus HT's for high intensity tillage, full inversion tillage divided by the organic carbon stocks under high intensity tillage. And you see that there's an additional storage of carbon, the upper layers but not in the deeper layers of soil. So what has been found actually in these different synthesthesis, these different meta analyses, is that no tillage allows to store much less additional carbon that we initially thought. A bit disappointing.

That this additional storage is very superficial, which is not interesting in terms of climate change mitigation. It is still very interesting in terms of climate change adaptation. You change the water retention properties. It is extremely interesting in terms of mitigating erosion.

You enhance the stability of the soil structure. The soil structure of the surface layer is better able to withstand rain events. And also, an interesting result is that it's highly variable among the studies have been performed. And to be honest, we are not able yet to explain why.

All the correlation, the studies were made, we cannot explain by climate. We cannot explain by soil. We cannot explain by management. There is something but as scientists, we have not yet identified the source of variability. So this is a question for the scientific community.

Yes, and one thing I want to add, here I'm talking about no tillage. I'm not talking about conservation agriculture. It was very well explained this morning. Conservation agriculture has three pillars. Increasing the diversity of the rotation, reducing tillage, covering the soil all year long with cover crops.

It's different when you compare conservation agriculture systems with more conventional systems. Then you have sometimes very large relative increases in soil organic carbon stocks.

Okay, but then these results that tillage is not that important in reducing the mineralization rates of soil organic matter really questions us as scientists. So I cannot give you the answer today but we have to revisit the underlying processes. We have to understand the variability. This is very important in terms of management. This is important also in terms of understanding soil functioning.

So what appears when comparing different practices? The different levers I showed you is actually, it seems to be much more efficient in terms of increasing soil organic carbon stocks to a certain depth, at least 30 centimeter. It is much more efficient to increase the inputs of biomass to soil by the different practices I show you rather than to try to decrease the outputs by decreasing erosion and mineralization. So this is important in terms of management. So cover crops, agroforestry, etcetera, should be really promoted.

Another focus I would like to make on increasing these inputs. One of the emerging results of the scientific literature in the last 10 years or so is that it is much more efficient to increase our carbon stocks to try to do it below ground from above ground.

What do I mean? That's what I presented here is the amount of carbon that is held in the above-ground biomass. A corn plant, for example, below-ground biomass, and what comes out of it in the soil carbon after several years. And we use stabilizer stocks [sounds like] to quantify that. And it appears that the yield in soil carbon that is, you know, the proportion between this and this, this and this, is much higher when you deal with root derived residues than with above-ground residues. So definitely, and this can be explained by how this organic carbon is incorporated in the soil through root health, through micro razor [sounds like], through exudates that go into very tiny pores of soils where they can be protected from decomposition.

So practices should aim at increasing root carbon inputs to soil and this opens a whole area of discussion about [inaudible] deep root systems, etcetera. Maybe we'll discuss that later in this, during this event.

Now if you store carbon, how much for how long? Let's, again, be quantitative. What I presented here is you have in the X axis time, in years and in the Y axis you have soil organic carbon stocks in tons per hectare. Let's consider you have the management, cropped field, management A, you implement cover crops, for example. If you do that for years, at some stage it's going to, the soil organic carbon stocks will increase and at some stage you will plateau. You will get to a plateau.

And I want you to notice two things. Storage is low. It takes time. And this is, questions the farmers' practices, questions old policies behind and storage is limited. We will not be able to ask soils to compensate for a way of life forever. Even if we implement the best practices in terms of sustainability [inaudible] carbon storage, at some stage, soils will have, we reach a new equilibrium.

And also, if you stop your cover crops, you will go back to the previous equilibrium. Storage is reversible. And if you had a prairie and you return it, you plow it, the loss of carbon is huge and rapid.

So priority, preserve what you have in your soils and second priority, be aware that it's slow, it's limited and it's reversible. And the amount of carbon you may store depends on the management you implement.

Here if you implement a third type of practice, you may obtain larger stocks. And one of the questions that really passionates us as scientists in this field is whether there’s an upper limit. Whether there's an upper limit and there is ideas that there would be an upper limit, maybe not for total carbon, but at least for the carbon that can be stabilized for decades because the, of the limited capacity of soil minerals. Here, for example, you have a mineral particle that I observed in electron microscopy with an organic layer that appear as dots here. So maybe there's a limited capacity of the minerals to protect organic matter from decomposition and allow it to preserve, to persist in soils for decades. So this is frontier in research.

So, yes, we want more carbon. We want some of it to turn over fast. We want some of it to turn over much slower where in order to be resilient and to contribute to mitigating climate change.

What stabilizes soil organic carbon for long times? Several processes. Complex, interacting processes. I want you, I want to give you a very rapid update on where we are on these processes.

So here I represent an organic molecule with microbes, bugs, they’re happy or unha-, because they can eat or unhappy because they cannot eat.

Chemistry, chemistry of the organic matter. Well, studies using C13 natural abundance have allowed to show that there are actually no rec-, no resistant organic ma-, molecules per se. No recalcitrance. Everything can be eating by microbes except maybe charcoal, pyrogenic carbon. So this is a really big change of parting [sounds like] in the community. We tend to think the opposite.

What was shown also recently is that the age of soil carbon increases with the abundance of very reactive fine-sized soil minerals. So long-term persistence, depending on soil type, can be explained by the mineralogy, the abundance of textures, the abundance of clay size particles, clays and oxides.

And a new type of process receives a lot, quite a lot of attentions that we realize that microhabitat conditions, really where the microbes live, and I have to show you a photograph, a photograph here you have two bacteria, one here and one here. You can see this one is surrounded by clay particles. That one is in the larger soil pore and this is, the food, the refrigerator. So this is their habitat.

So we are realizing that microhabitat conditions control the activity of microorganisms and their ability to access to food, to access to this food and to decompose it. And this would explain the effect of climate, water availability and also of management, tillage on decomposition of soil organic matter. And there are also a wide range of biological regulations. We will hear more tomorrow about it, especially with networks, and this inter-, networks and interactions are not explained but, again, they should explain the effects of management.

So a wide range of processes explaining the persistence of organic matter. Organic matter persistence is somehow an ecosystem property rather than the single processes taking place.

Okay, so let me have . . . thirsty. So we saw how to do it. So where to do it now? Where to do it? What I propose, I propose you [inaudible] of the landscape is to do it where you need most organic matter, in the organic pool plots. Why? Because maybe you will be able to store more, but also, because you will have more benefits, you can expect more benefits in terms of soil properties. Sensitivity to erosion, for example. Provision of nutrients. At the scale of the soil profile, the rule should be, if you can, go deep. Go deep why? Because carbon in deep soil layers are stored for much longer times.

What you have here, again, this is a very recent result, is the abundance of pools, imagine artificial proportions of organic matter that have ages, you can see here, 3 years, 10, 3 years, 10 years, 30, 20, 1-, 1-, 100, 300, 1,000 years, 3,000 years. And you can see that the proportion of organic matter residing for shorter times is much larger in the soil surface layers then at depths where most organic matter persists for centuries, millennia. So if possible, go deep.

And about the scale of the planet. At the scale of the planet, I would say, and there was a very interesting converence at FAO on that regarding soil organic carbon that the priorities are not the same in the different regions of the world. In high latitudes and in regions where you have peatland, the priority is to protect these huge carbon stocks.

So everything is tuned to our climate change mitigation. Preserve them from climate change, from excessive drainage, so this causes economic problems. There are trade-offs to fight. It’s not an easy question at all but the priority, preserve the carbon in peatlands.

While in drylands, the priority is to increase soil organic carbon stocks. Soil organic carbon stocks in these areas of the world are very small. Are very small because of climate, because of management, because of different regions. And the priorities to increase soil organic carbon for food security to improve soil properties, to improve soil fertility. So different areas of the world, different priorities.

Now we've seen proposed avenues of where to do it. What I would like to discuss with you, and I think the question would come, you would be able to ask me questions and I [inaudible] okay, is it possible now? Is it possible everywhere? Well, no. No. [laughs] But it should not restrain us from trying. But, no, it's not possible everywhere.

There are different barriers. Biophysical barriers, socioeconomical, political, economical barriers.

Biophysical barriers: to grow plants, and we have discussed that [inaudible] this morning, you need nutrients. You need nitrogen. You need phosphorous for plant production. But also, and this is a research result, to turn, you know, a liter into humus, into soil carbon, you'd also need nutrients. You need a certain proportion of carbon, nitrogen, phosphorus.

And this nitrogen might be limiting. And actually there has been estimates recently of the amount of nitrogen that would be needed if we, let's assume, the idea was let's assume, okay, that we can increase the world's soil carbon stocks by the amount needed to compensate the annual increase of CO_2 in the atmosphere, 3.5 gigatons of CO_2, of carbon. Not of CO_2, of carbon. Then what you would need is 10 times less of nitrogen. That's huge amounts. Huge amounts.

So the answer could be mineral, in theory can be mineral fertilizers. But this raises huge problems in terms of also greenhouse gas emissions related to nitrogen fertilizers emission and of the sustainability and of the environmental impacts of all carbon systems and of the dependency of farmers towards external nitrogen mineral sources.

There are other ways to do, well, and again, it's very different in different areas of the world. Rattan Lal was insisting this morning that in some areas of the world, what is really limiting production is nutrients. And you might have to bring in mineral nutrients because there is not enough resources on site.

But in other areas of the world then, I live in such an area, Northern Europe, well [inaudible] Europe and I think probably live [inaudible] the case also, our agriculture is associated with nitrogen surpluses. And then these in essence could be used to enhance organic carbon stocks. For example, by implementing cover crops.

In our country, in Europe, the first reason for implementing cover crops is that the cover crops take up, assimilate the excess nitrogen, the excess nitrates in the soil. So it's a way to protect the quality of the water. And this nitrogen is, then goes back into the soil later on when the cover crop is destroyed.

Other ways to do it is to favor biological nitrogen fixation, legume plants. And also to promote livestock and urban waste recycling. And also this was discussed this morning. They c-, I don't, I think it's fairly different in your country maybe than in mine. I live in an area of the world where the density of population is high. Where we have limited space and we have big cities.

And we are working in our department, for example, we are working on short cycles of nutrients and carbon, between the cities and between the surrounding agriculture, the prairie, urban agriculture because all the biomass goes as food within the city, Paris in my, in our case. And the waste is coming from that as compost could be then added back to the soil.

So we are working to estimate, to develop such circuits of carbon, nitrogen, phosphorus, potassium, etcetera. Okay, so huge demand but definitely the need for nutrient shows that increasing soil organic carbon stocks can be limited by this and the response has to be spatially differentiated. Not all areas of the world are equal. Not all areas of the world have the same potential capacities and access to nitrogen and phosphorus.

Well, to grow biomass, you also need water. And this might be limiting in some areas of the world. You need biomass, of course. And you need soils. Again, if you have no soils, you cannot store any carbon. That's obvious, but I think it's important to reminded. And you can lose soils by erosion so here we have a synergy between protecting soils from erosion by increasing soil carbon and we need to protect soils from erosion to be able to store carbon in them.

And, again, maybe this is because I live in a densely populated area, but soils are increasingly consumed in Europe. I don't know, I have no idea about the numbers in the U.S. but in France and Europe, it is really huge, the land that we consume for urbanization. And all this land, well, it's not, does not, it's not a universe underfoot anymore. There's no carbon stored anymore. It does not provide the same ecosystem services anymore. We have to save our land in terms of service area. We have to be careful about that. We have to implement programs to try to protect the land from completely disordered urbanization.

So this is for the biophysical barriers. Now there are other barriers, agronomical, societal, economical.

Most of the food produced in the world comes from small holder family farming. And these may be less, it is less easy for them to take risks. And they might, so adoption by farmers is really depending on the economic profitability. The benefit they might be, they might have. And there is, there's awareness needed but there's also tools to show them that it can be profitable. There can be a lack of knowledge and skills. There can be a lack of resources. We have also this morning, say that's in different areas of the world dung is used for heating and cooking, for homework activities. And the crop residues are fodder for the animals. So to put them back in, to put the fodder, to put the residues back into the soil or feed the animals, that's not an easy trade-off.

There's a need, there might be a need of credit, of ability to invest and land tenured security also. You will not invest in your land and your soil if you have, if you don't know how long are you going to crop this particular plot.

And so there's a need for extension services support and incentives of different types. We have also been discussing that this morning. Now is it dangerous? Is there any danger as was stated with storing more carbon in soil? Well, to be honest, it's essentially a win-win situation but there are cases where, yes, there are dangers.

There are dangers. Why? So there’s a dark side of organic carbon stocks and I really think it’s important to be aware of the dark side in order to fight against it, in order to find the good ways to proceed.

I’m again showing you still the same graph. I showed you that it could be, the decomposition of organic matter provided, could release all the greenhouse gases, could release ammonium turned into nitrate.

So more organic matter can mean, and it depends on the [inaudible] climatic conditions, it depends on the water situation of your soil, for example. Can release more, can result in more greenhouse gas emissions and reduce water quality. But this is essentially affected by the practices, by the management that is implemented. And also more biomass can be obtained by adding more mineral fertilizers, by adding more pesticides, by consuming more water. And these are definitely negative effects.

So it’s essentially controlled by management options. And management options have to be taken in order to avoid these dark side of organic matter storage. So it’s not essentially due to the organic matter. It’s more due to the way you do, the management of options you may take to increase the soil organic matter content for a virtuous objective, you might have detrimental ways to do it. Well, we are used to that in many areas of our everyday life.

Is it possible to have negative social impacts? Again, in theory, yes. I hope it will not happen but in theory, it’s possible. You can turn agriculture land into carbon farming just for the biomass, just for storing carbon, just to get carbon credits. And this would put harm on, put pressure on land tenure and family farming.

What it means then is that the changes in agriculture have to be put under an umbrella. An umbrella like agroecology in terms of impact to the environment and have to be associated with agronomical, environmental, social, economical, and political analyses. These are absolutely needed. We need a framework. We needed a framework to be sure that for a virtuous objective we do not do harm.

Now I think I said the landscapes, so how to go forward? I have to say that the situation has really changed over the last years. There is a series of initiatives that have really changed the landscape and that, make that soil is now becoming apparent in public policies, at least in decision makers’ language. One of the important ones is the setup of the sustainable development goals and soil is present in four of them, it mentions four of them, and is very central and there's an objective, quantitative objective regarding soil carbon for the sustainable development that is life on land.

The FAO set up a global soil partnership. One of the results was to [inaudible] to produce a new soil carbon map that is better than previous ones. There was an international year which was a fantastic year for raising awareness among, and I think I was especially sensitive to that, among policymakers in particular, but among the general public, farmers, urbanists, land planners. In many cases, they heard about soils for the first time. They realized that soils were not, was not inner, soil was a whole world and a fruit, this whole universe and of a fruit.

The ipbes, you might not know this logo. Ipbes is International Panel on Biodiversity and Ecosystem Services. There has been this year the first series of world assessments on land degradation and restoration and on the state of ecosystems and biodiversity and state of resources in different areas of the world. Again, it increases awareness.

And there is the Four Per Mil initiative that was launched by the French government at the COP21 in Paris in 2015. So what is this initiative? It is a multi stakeholder initiative that aims, as you see, as I have written it, to increase organic matter and promote soil carbon sequestration through the application of appropriate farming and forestry practices in order to contribute to food security, climate change mitigation and adaptation to climate change. Three major objectives.

And four per mil, where does it come from, this title? Well, if you refer, I showed you a graph with the global carbon cycle and it said, it showed that an annual increase of four per mil, that is point four percent of the world soil carbon stocks would compensate the annual fossil fuel emission of all planets. So this is a back-of-the-envelope calculation. This is to give you an order of magnitude. And it has become the title of the initiative. And I often say when I speak about this initiative because I'm a member of the international scientific committee of this initiative, that it is probably the best thing of this initiative and the worst.

And the worst why? Well, there's the power of numbers, the simplicity of numbers. And also four per mil, it's just less than one percent, easy. So it appears very positive. It appears easy to make. And it’s exactly like, it’s a political tool. And it, actually it was launched by a ministry. It was not launched by scientists. It’s the equivalent, in a sense, to the 2-degree target. We all know about the 2-degree target. And to the eat five fruits and vegetables a day, I guess you all know about that. And we all guess that scientists working in nutrition might think that maybe it’s not exactly what should be done. Or maybe it’s not enough to say that. Well, it’s exactly the same for the four per mil. It is efficient, but it has to be seen as an aspirational target. To maintain the existing soil organic carbon stocks and if possible, to increase them.

There’s a lot of debate in the scientific literature and this is good about where this is achievable locally. It is . And wh-, in some places, and whether it is achievable globally. I don't know yet. There’s a lot of debate. But even though it is not achievable in terms of numbers globally, even though we succeed only one per mil increase, that would be such a victory also, even maintaining the present soil organic carbon stocks is a challenge. So we have to go forward.

So what does the initiatives that it tries to engage, it advocates, engages. It also tries to help projects that aim to increase soil organic carbon stocks by proposing criteria to fra-, to have a framework. Not to go into any direction with harmful effects. And it has proposed research priorities.

Now I’m going to conclude. So is organic matter a solution to global challenges? Well, I would like to say two things. Yes, it’s one of the solutions. So it has to be taken because it brings many benefits. And it’s not only to the global challenges but also local ones, the quality of the crops, the quality of the fields. It brings many benefits. And to conclude, I would like also to say that, yeah, to recall that the goal is to maintain an increase of soil organic carbon stocks.

It is achievable locally. It has to be spatially differentiated. Conditions are so different across the planet. It has a cost. We should not avoid discussing that.

It is not a silver bullet. It will not ra-, be a solution to all problems. So it’s not THE solution. It’s one of the solutions.

A wide perspective is needed. Not only carbon but soil organic matter. Not only, not only biophysical aspects but also socioeconomic aspects, have a wide perspective. Embrace the whole thing with a very integrated way, with a holistic perspective. It needs, it requires multiactors engagement. The actors infinite, they are the farmers. And there’s a need of a framework, sustainable soil management, agri-, the type of agriculture do we want, what type of agriculture do we want? Human rights also.

And I think, as a scientist, I think it is very exciting because such an initiative questions you about how to maintain, how to put forward political efficacy and scientific rigor. So as a scientist, I find this extremely exciting and I would like to thank you for your attention.