Submission of the International Fertilizer Association to Koronivia item 2.c.

Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management.

Key messages:

- The fertilizer industry is appreciative of the KJWA's decision to include soil carbon, soil health, soil fertility and water management in its work program, and takes this opportunity to address the plant nutrition elements that fit into this topic.
- Soil health and soil fertility depend on effective and efficient plant nutrition. The fertilizer industry therefore endorses the FAO's 2017 Voluntary Guidelines on Sustainable Soil Management that call for the adoption of best management practices such as Integrated Plant Nutrient Management (which entails applying mineral fertilizers combined with organic fertilizers).
- Best fertilizer management practices do not only promote soil health and fertility, but also assist with reducing GHGs from fertilizer application[1]. The fertilizer industry is committed to reducing these emissions through the dissemination of Fertilizer Best Management Practices (FBMPS), **the 4Rs of Nutrient Management** (which entail applying the Right nutrient Source[2], at the Right Rate, at the Right Time and in the Right Place), and knowledge transfer, which it does with its partners from governments, NGOs, research organizations, scientists and farmers.
- We welcome the inclusion of SOC in the scope of item 2.c due to its importance to the agricultural sector's mitigation potential. Healthy soils can store up to 1.500-4.500 million tons of CO_2- eq each year, which could significantly reduce global GHG emissions[3]. We strongly support the scientific community's call for the KJWA to commit to increasing global soil carbon stocks[4], while further research and analysis is still required (i.e. on permanence and maximum carbon storage capacity), it is considered the most promising mitigation measure for the agricultural sector. Ultimately, the KJWA may be able to provide guidance to Parties on how to increase their SOC by taking into account their countries' and regions' specific soil conditions and needs.
- Much emphasis is appropriately placed on GHGs emitted by fertilizer application (both mineral and organic). Yet fertilizers also make an important contribution to the creation and preservation of carbon sinks in forests and agricultural soils. First, by increasing soil health and soil fertility, and thus productivity of arable land, pressure is taken off forests (when deforestation regulations are in place and implemented) and emissions linked to land-use changes are reduced.

  Second, fertilizers increase the large terrestrial pools of carbon in agricultural soils by improving ratios of Carbon to Nitrogen and increasing biomass. Our comments below expand on the role of fertilizers in soil carbon sequestration.

[1] As explained in: Stirling CM. 2018. Accounting for mitigation of N-fertiliser emissions at national and project scales. CCAFS Working Paper no. 230. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

[2] Note that the Right Source encompasses the right nutrient, combination of nutrients and different fertilizer products, including products which modify the release of nutrients such as slow- and controlled-release and stabilized fertilizers. For more information on the 4Rs, please consult the Nutrient Management Handbook IFA, WFO and GACSA First edition, November 2016.

[3] Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O. 2007. Agriculture. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, eds. Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. pp. 498–540. (Available from http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter8.pdf)

[4] https://ccafs.cgiar.org/news/media-centre/press-releases/scientists-call-8-steps-increase-global-soil-carbon-climate-action#.XLmkgOgzaF4

Plant Nutrients and Soil Carbon Sequestration

Creating and preserving carbon sinks

Whereas the application of both organic and mineral fertilizers leads to GHG emissions, which can be reduced through FBMPs, Slow- and Controlled- Release and Stabilized Fertilizers, and the 4R global framework of nutrient stewardship[5], fertilizers also play an important role in creating and preserving global carbon sinks:

Fertilizers reduce pressure on forests and help avoid land use changes by increasing the productivity of available arable land. This is crucial for climate change mitigation, as deforestation and land-use conversion combined represent about 30–50% of agricultural emissions and about 4–14% of global emissions[6]. Fertilizers increase soil health and soil fertility by replacing the nutrients taken up by harvested crops or lost by unavoidable leakages to the environment; they stimulate microbial activity, improve soil structure, and increase their water holding and cation exchange capacity. Thanks to advances in crop productivity and efficient fertilization, about **one billion hectares of land have been preserved** from conversion to cropping between 1961 and 2005, **leading to carbon emission savings of 317 to 590 Gt CO_2-** eq from not converting that area[7].

Fertilizers also help to build carbon sinks in agricultural soils by improving their Carbon to Nitrogen (C: N) ratios[8] and maximizing their biomass production, which results in higher levels of soil organic matter (SOM) and soil organic carbon (the core element of SOM). This is also very significant for climate change mitigation, as soils represent the largest terrestrial pool of carbon: they can store up to 50-300 tons of carbon per hectare, which is equivalent to 180-1100 tons of CO_2 per hectare. Soils of crop lands, grazing land and rangeland globally can potentially store 1.500-4.500 million tons of CO_2 equivalent per year[9].

According to the IPCC, this represents 89% of agriculture's future mitigation potential, and 70% of this potential is in low- and middle- income countries.[10] Another study further estimates that agricultural practices that reduce GHGs and increased SOC could reduce global emissions by 1.500- 1.600 CO_2 equivalents tons per year[11].

Integrated Plant Nutrient Management: best proven method for soil carbon sequestration

Research has found that **Integrated Plant Nutrient Management**, i.e. the combination of mineral and organic fertilizers, results in the highest levels of SOC: A long-term experiment in Münchenberg (Germany)

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[5] Decreases in agricultural GHG emissions linked to the adoption of fertilizer BMPs have been already been observed in different parts of the world: in the United States, farmers observed a 7-14% reduction in N_2O emissions following intermediate or advanced 4R implementation; in India, they resulted in net CO_2- eq emissions reduction in per hectare and per ton of crop yield; and in Europe, they resulted in the highest levels of NUE compared to other plots.

[6] Vermeulen et al. 2012, based on van der Werf et al. 2010 and Blaser and Robledo 2007 in CCFAS Big Facts: https://ccafs.cgiar.org/bigfacts/#theme=mitigation&subtheme=indirect-emissions

[7] Burney J.A.,S.J. Davis, and D.B. Lobell (2010) Greenhouse gas mitigation by agricultural intensification, Proc. National Academy of Sci. 107(26): 12052-12057.

[8] Soil microorganisms need to maintain a balance between C and N to be healthy: an application of N-poor crop residues, like cereal straw, will require soil organic matter to re-equilibrate its C:N ratios which can lead to C losses in the form of CO2 emissions. However, using residues from N-fixing legumes or supplementing N-poor residues with N fertilizers can help achieve a better C:N balance in soils and thus increase soil carbon sequestration.

[9] Smith et al. 2007

[10] Smith et al. 2007.

[11] Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O, Howden M, McAllister T, Pan G, Romanenkov V, Schneider U, Towprayoon S, Wattenbach M, Smith J. 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences 363:789 – 813 (Available from http:// rstb.royalsocietypublishing.org/content/363/1492/789.full)

showed that after 41 years the carbon stocks of soil were higher when organic inputs were combined with mineral fertilizers, compared to only organic inputs or only mineral fertilizers. Similarly, in Israel, a long-term experiment showed that after 30 years, soil carbon stocks were higher with IPNM compared to only organic inputs or only mineral fertilizers.[12] **With IPNM, mineral and organic fertilizers play complementary roles:** mineral fertilizers supplement the nutrients provided by organic fertilizers with concentrated, consistent and plant-accessible nutrients.[13] Organic fertilizers, when available in sufficient amounts, provide beneficial soil organic matter that improves soils' health, fertility, structure and water retention capacity.

For countries where soil fertility and SOC are currently low but where the IPCC predicts an important mitigation potential, IPNM presents several benefits: the combination of mineral with organic fertilizers has proven to produce the highest yields possible[14], to improve soil health and reduce nutrient losses to the environment.

While calls for using only organic fertilizers are strong in certain parts of the world, most agronomists agree that IPNM is the best option for optimized plant growth and SOC. It should also be noted that **applying solely organic fertilizer does *not* reduce agricultural greenhouse gas emissions**[15], and organic fertilizers in the form of animal manure are particularly susceptible to leaching and runoff with serious implication for water quality. (Note however that the industry also offers products (nitrification inhibitors) that help reduce nitrate leaching and N_2O emissions from organic fertilizers). Moreover, organic fertilizers have variable nutrient content, and without regular testing there is a greater risk of either applying excessive amounts of certain nutrients or too few, which can damage plant and soil health[16].

IPNM and the 4R Principles:

The fertilizer industry therefore promotes the adoption of Integrated Plant Nutrient Management, combined with the 4R global framework of nutrient stewardship (using the right nutrient source at the right rate, time and place), to ensure optimal nutrient use efficiency (NUE), increase SOC and reduce GHGs from managed soils. Moreover, IPNM and the 4Rs can help farmers to adapt to climate change by strengthening their crops' and soils' resilience to changing weather patterns and by making the best use of resources like water.

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[12] Hijbeek, 2019.

[13] The nutrients of mineral fertilizers are formulated to be readily available to plants, absorbed directly through their roots and leaves. As a result, they can be applied just at the right time they are needed for the most efficient uptake during the plant's growth cycle, maximizing their efficiency while minimizing losses to the environment.

[14] This has been observed in Sub-Saharan Africa, where agricultural research across numerous countries and diverse agro-ecological zones has shown that highest and most sustainable gains in crop productivity per unit of nutrient were achieved from the integrated use of mineral and organic fertilizers

[15] Decock (2014) found in a meta-analysis of many studies that manure emitted an average of 40% more nitrous oxide than synthetic N, per unit of N applied. Source: dx.doi.org/10.1021/es4055324 | Environ. Sci. Technol. 2014, 48, 4247−4256

[16] It should be also added that the Nutrient Use Efficiency (NUE) of organic fertilizers is lower than of mineral fertilizers: With 60% equivalent effects, for each kg mineral fertilizer N, 1.6 kg organic derived N would have to be applied (see German Regulation "Düngeverordnung": https://www.bmel.de/DE/Landwirtschaft/Pflanzenbau/Ackerbau/_Texte/Duengung.html).

Closing Research Gaps

Given the high potential of SOC for climate change mitigation, the fertilizer industry supports the scientific community's call for KJWA to commit to increasing global soil carbon stocks[17], while also addressing remaining questions, such as:

- How to ensure SOC permanence: Agronomic practices that enhance soil carbon sequestration like IPNM need to be applied permanently in order to maintain the new soil carbon equilibrium and avoid carbon losses. Parties should therefore be careful in choosing agronomic practices that will guarantee increased SOC and be aware of the need of applying them continuously in order not to lose carbon stored in soils.
- More research is needed on the maximum of C that can be stored in soils: indeed, research shows that there are limits to how much carbon can be stored in soils: eventually SOC reaches a plateau, where no additional carbon can be stored or lost. This could represent a caveat to SOC's mitigation potential that needs further examination by the KJWA.
- More research is needed on the potential trade-off between carbon sequestration and noncarbon, i.e. N_2O, GHG emissions, which can reduce the GHG mitigation effect of carbon sequestration consistently.

Different regions call for different measures

Fertilizer management practices, yields and soil conditions vary importantly across regions, therefore recommendations on fertilizer use and climate change mitigation need to take these differences into consideration. Special attention is required for many developing countries, and particularly in Sub-Saharan Africa, where fertilizer use and crop yields tend to be low (in average: 16 Kg nutrients/ha): in these countries, increasing nutrient inputs (that leads to increased biomass and increased SOC) can create positive feedback loops between soils and crops and increase food security.

It is also important to bear in mind that SOM accumulates more easily in wet soils. Therefore, water-scarce environments or countries affected by drought should implement specific adaptation measures (and provide growers with the appropriate training) that will help maintain or increase their SOM, for instance crop residue management that provides nutrients, captures better rainfall, increases infiltration and soil moisture content, provides a cover to protect soil from being eroded and reduces evaporation. **Fertigation**, the combination of fertilizer with irrigation water, has also proven to be efficient in maximizing yields in water-scare areas, as well as preventing water from being wasted in conventional irrigation systems.

[17] https://ccafs.cgiar.org/news/media-centre/press-releases/scientists-call-8-steps-increase-global-soil-carbon-climate-action#.XLmkgOgzaF4