Submission to Decision FCCC/SB/2018/L1 on

The Koronivia Joint Work on Agriculture (KJWA)

Topic 2(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems

***Signatories[1]*: ABDN[2], CAES, CEA, CEIGRAM, CIMMYT, CIRAD[2], GASL, IBC&SB, IIASA[2], INIA, INRA[2], IRD[2], IITA[2], ISRIC[2], LRI[2], MSU[2], STC, ULS, VAAS**

As a group of research and higher education institutions and programs-—hereinafter referred to as 'the Group'—, observers and non-observers to the UNFCCC, we welcome decision 4/CP23 and on the Koronivia Joint Work on Agriculture (KJWA), as well as the subsequent submissions by Parties, observers and non-observers to the UNFCCC, as well as the decisions FCCC/SB/2018/L1 and FCCC/SB/2018 L7 taken at SBSTA/SBI 48 and at SBSTA/SBI 49, respectively.

The Group welcomes the opportunity to submit its science based views for the workshop taking place at SBSTA/SBI 51 in November 2019 on topic 2(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems. In this submission, the Group will refer to former collective scientific submissions to the KJWA on topics 2(a) and 2(c).

(A) Key messages

- Topic 2(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems and topic 2(c) Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management are strongly related

- Soil carbon sequestration (SCS) potential is linked to the availability of mineral nutrients, such as Nitrogen (N), and Phosphorus (P Mineral nutrient availability can be a limiting factor for SCS) because dead plant biomass (e.g. roots turnover) is an important C input to soil that is increased when plants grow faster... Globally, mineral deposits of P are finite and unevenly geographically distributed. Mineral N fertilizers contribute as powerful sources of groundwater pollution and greenhouse gas (GHG) emissions (direct N20 emissions on-fields and indirect emissions during mineral fertilisers production and transport).

1 The acronyms of the signatories are explained at the end of the submission.

2 Institutions and programs members of the CIRCASA -Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture- consortium https://www.circasa-project.eu/About-us

- Access to affordable fertilizers is a limiting factor to increase yields in smallholder farming systems in Africa. Trade-offs between food production and fertilizer use (mineral and organic) have to be considered in different manners between developing and developed countries;

- Nutrient use efficiency is a synthetic indicator to assess and monitor farm performances and then to define policies for sustainable and resilient agricultural systems;

- Better nutrient recycling within farming systems, improves N use efficiency, reduce farming system dependency on imported resources and then increase farming systems resilience; more self-sufficient farming systems are less exposed to resources prices fluctuations (see for instance the strong dependency of European livestock production to soybean imported from south America);

- Organic fertilizers like manure, trough livestock's biomass recycling capacity, have the potential to supply agricultural systems with nutrients and valuable micronutrients, while reducing waste treatment and discharge related CH_4 and N_2O emissions. Additionally, organic fertilizers, if produced through recycling and valuation of wastes, could substitute to mineral fertilizers that could result in mitigation potentials on GHG emissions, especially on indirect emissions (, fossil energy consumption); further studies have to be conducted to better quantify this mitigation potential under tropical conditions

- N-fixing plants, mycorrhizae, plant growth promoting rhizobacteria can enhance plant nutrient availability and can contribute to addressing the limited availability of N and P to increase SCS and improve soil health;

- Enhancement of interactions between livestock and crops, as well as trees and crops, can have strong beneficial effects on nutrient availabilities;

- Recycling of biomass to produce organic fertilizers must be carefully assessed at local scales if intended for large-scale implementation to avoid conflicts of uses (e.g. fodder, fuel) especially in areas where biomass availability is limited. Governance, socio-economic arrangements, and capacity building are key issues for a sustainable recycling of biomass in agricultural systems; Innovative transformation of waste biomass should be considered to limit GHG emissions during the process and to increase the duration of SCS.

- Increasing SCS can improve food security and contribute to adaptation to and mitigation of climate change. It can also have a range of additional co-benefits such as contributing to soil structuring, reducing soil erosion, increasing soil water holding capacity , have an impact on below and partly above ground biodiversity and related ecosystem services, and nutrients cycles. These co-benefits make the active management of soil organic carbon (SOC) pivotal to realizing the synergies among the Rio conventions, achieving the Sustainable Development Goals and avoiding trade-offs.

- Improvements in SOC through sustainable land management (SLM) have strong beneficial impacts on soil properties and processes and therefore on land restoration. Launching and implementing SLM approaches and techniques to increase SOC stocks require participative and inclusive engagement with farmers regardless the size of their farm. Moreover, these activities need to provide locally appropriate and integrated technical solutions in agricultural systems and landscapes. In addition, sharing the importance and implications of improving SOC stocks with policy makers, interested stakeholders and citizens is crucial.

- Maintaining and increasing SOC stocks requires continuous effort to avoid the release of the stored carbon, therefore SLM practices, including management of import and export of biomass, must be secured for the medium term (~ 10 years) to the long term (> 20 years). Therefore, related policies and measures including monitoring cycles should be integrated into broader coherent and structural policies and backed by continuous scientific evidence and advice, taking into consideration the medium and long term timespan needed for effects of good practices to be well captured with adequate resolution.

- Enhancement of interactions between livestock and crops (i.e. biomass recycling), as well as trees and crops, have strong benefits on nutrients recycling, availability and use efficiency;

- Mobile livestock can play an important role in nutrient spatial redistribution; some farmers (in Sub-Sahara Africa) use free-grazing livestock to transfer nutrients from rangelands to croplands, and concentrate nutrients in croplands;

- Considerable nitrogen losses can occur along the nutrient cycle (higher losses rates under tropical conditions), especially at the manure storage and spreading stages; alternative technics (like covering manure heaps, in-soil manure incorporation, etc.) improve nitrogen use efficiency of farming systems;

- Livestock urine is an important and under-estimated source of nitrogen (ammoniac N) with large risk of N losses (volatilisation, lixiviation); better urine collection and use is a promising option to increase nitrogen use efficiency of farming systems, in low input systems in particular.

(B) The context

The objective of the Paris Agreement is to maintain global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. To achieve this, net zero GHG must be reached in the forthcoming decades. Globally, agriculture and land use change (AFOLU sector) are responsible for about a quarter (~ 10 - 12 $GtCO_2eq$/year) of anthropogenic GHG emissions mainly from deforestation and agricultural emissions from livestock, soil and nutrient management. About 20 to 25% of GHG emissions from AFOLU sector are related to nutrient and manure management.

Global emissions from manure, as either organic fertilizer on cropland or manure deposited on pasture, increased between 1961 and 2010 from 0.57 to 0.99 $GtCO_2eq$/year. Average emissions increased by 1.1%/year. Emissions from manure management increased from 0.25 to 0.36 $GtCO_2eq$/year, resulting in average annual rates of increase of only 0.6%/year during the period 1961 – 2010. Emissions from synthetic fertilizers increased much faster at an average rate of 3.9%/year from 1961 to 2010, with absolute values increasing more than 9-fold, from 0.07 to 0.68 $GtCO_2eq$/year. Considering current trends, synthetic fertilizers will become a larger source of emissions than manure deposited on pasture in less than 10 years and the second largest of all agricultural emission categories after enteric fermentation. Close to three quarters (70%) of these emissions were derived from developing countries in 2010.
Therefore, there is considerable potential for improved nutrient use and manure management to reduce emissions.

In their Initial Nationally Determined contributions (INDCs), 104 countries included the agricultural sector in their reduction emission effort and 126 countries listed it as a priority for adaptation.

Efforts to improved nutrient use and manure management towards sustainable and resilient agricultural systems would contribute to food security, adaptation to and mitigation of climate change and to achieving the Sustainable Development Goals, including but not limited to SDG 2 (zero hunger), SDG 13 (climate action) and SDG 15 (land conservation and restoration).

Several recent studies recommend improved nutrient use efficiency and manure management in agricultural systems. In June 2019, member countries at the 41st session of the FAO Conference endorsed the International Code of Conduct for the Sustainable Use and Management of Fertilizers. The Code aims to guarantee an effective and efficient use of fertilizers and addresses issues of global importance including "Global food production and food security" and "The preservation of fundamental ecosystem services". ". Improved Nutrient management is a win-win solution for agricultural production, climate change mitigation and adaptation and pollution reduction.
Efficient manure management is a key element of nutrient economy and SCS

To provide scientific guidance to countries to (a) build policies and projects on improved SOC stocks and (b) enhance ambitions in their INDCs in 2020 in this sector, several initiatives have been launched:

- The development of the new Methodology Report to refine the current Intergovernmental Panel on Climate Change (IPCC) inventory guidelines (2006 IPCC Guidelines for National Greenhouse Gas Inventories), was carried out by the Task Force on National Greenhouse Gas Inventories (TFI) in accordance with the decision taken at the 44th Session of IPCC in Bangkok, Thailand, in October 2016. The new Methodology Report titled "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" (2019 Refinement) was adopted and accepted during the 49th Session of the IPCC in May 2019.

- The Scientific and Technical Committee (STC) of the 4 per 1000 Initiative (4 per 1000 STC) produced as Set of Reference Criteria for Project Assessment on agricultural soil carbon sequestration.

- The Global Research Alliance on Agricultural Greenhouse Gases (GRA) launched in June 2019 an Inventory and INDC Support Network to improve the evidence base and to better connect governments and relevant expertise to subsequently improve the quality of agricultural INDCs and the way their achievements are reflected by national GHG inventories.

(C) Science based knowledge for policy advice in relation to topic *2(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems*

Linkages between improved nutrient use and manure management and improved soil carbon

Carbon is the main component (more than 58%) of soil organic matter (SOM). It is strongly coupled to nutrients such as N and P, which show constant ratios to C for the stable portion of the soil organic material in a wide range of global soils. For example, SOM has an average C to N ratio of 12..This implies that in mineral soils, the availability of nutrients, in particular N and P, is needed to achieve SOC stock increases, because they (1) increase plant production and therefore carbon input into soil and (2) are needed for microbial activity to build up stable (mineral associated) SOC. Therefore, it must be considered that improving SOM storage also stores nutrients in the form of N and P. On the other hand, coupling of nutrients and carbon in SOM prevents leaching losses and pollution of waterbodies.

Due to its key role in beneficial soil functioning, SOC is often considered a proxy for soil health and soil fertility, particularly with positive or synergistic effects on nutrient cycling, yields and yield stability, biodiversity, water infiltration and storage, and reduced wind or water erosion.

From improved soil carbon stocks to soil carbon sequestration (SCS)

(SCS) is the net CO_2 removal from the atmosphere to the soil, where the carbon is stored in soil organic matter. Therefore, practices to improve SOC stocks, when considered in the perspective of climate change mitigation, require a trade-off analysis at the relevant scale, often at the landscape scale. SCS practices involving mineral or organic N fertilization could generate GHG emissions and organic fertilization could lead to organic carbon transfer within landscapes. Such trade-offs must be assessed in a holistic approach, which could be based on the concept of a "climate-smart landscape" to reflect on the possible synergies between production, mitigation and adaptation.

Practices that improve simultaneously nutrient use efficiency and manure management and SCS

Nutrient use and manure management may be aligned with SCS, for instance, by:

- optimising nutrient management through improved farm management practices
- Improving manure management (collection, storage, biological transformation) to conserve and stabilize nutrients and use them efficiently either as organic N fertilizer (liquid manures, residue of biogas production) and/or maximizing their role as a source of C for SCS with solids forms (solid manures, compost, solid phase) having a very slow release of N and to cope with this dual property in a proper way;
- Production of normalized mineral N (and P) fertilisers from manure in a competitive way compared to the production of synthetic mineral fertilizers;
- incorporating spatially-differentiated SCS strategies into precision agriculture
- using N-fixing plants (notably forage legumes), mycorrhizae, plant growth promoting rhizobacteria to enhance N and P availability for plants and reduce mineral N fertilizer;
- using exogenous amendments in the form of farm manure and compost if this biomass would otherwise be burned or deposited into landfills resulting in emissions of methane.
- innovative waste management techniques may increase the value of organic fertilizers by reducing their CO_2 emissions during production and/or after soil application
- diversification of landscapes by enhancing crop-livestock integration, and introduction of legumes, trees and crops associations (e.g. agroforestry)
- integration of crop-livestock production systems to close nutrient cycles and develop conservative agriculture;
- adoption of practices and development of a panel of crops allowing for permanent soil cover and closed nutrient cycles (crops with complementary cultivation requirements, pastures, permaculture, etc.).

Scope for reducing waste management induced potent GHG emissions

The current fate of most manure and other organic waste leads to highly significant CH_4 and N_2O emissions. Well-managed recycling schemes would reduce most of these emissions and losses:

- Prevailing liquid manure storage systems (pits, lagoons) are very significant sources of CH_4 emissions and N losses through ammonia volatilization, a share of which leads to N_2O emissions after deposition. Recycling schemes shortening liquid storage reduce GHG emissions and preserve valuable organic nitrogen;
- These observations also apply to many other significant organic waste flows discharged to waterways. Secondary treatment in prevalent sewage plants in particular leads to technically avoidable GHG emissions and N losses;
- Similar benefits are to be expected from improved solid manure management, the pile stocking of which creates conditions for N_2O emissions;
- Current land spreading practices of organic waste with a large mineral nitrogen share also lead to large atmospheric N losses. Even basic waste processing techniques allow to reduce such losses and make a larger nitrogen share available to crops;

- Lastly, it should be noted that synthetic nitrogen fertilizer applications also lead to substantial atmospheric N loss. Their substitution with fertilizers of a large organic nitrogen share also contributes to reducing indirect N_2O emissions from agriculture.

Key specificities of waste and biomass recycling

Recycling of biomass to produce organic fertilizers must be considered at large scale to avoid conflicts of uses (e.g. fodder, fuel) especially in areas where biomass availability is limited. Governance to maintain and socio, economic and cultural wellbeing are key issues for a sustainable recycling of biomass in agricultural systems.

The recycling of organic wastes from domestic activities and urban areas as organic fertilisers is an opportunity to transfer organic carbon in ways that increase SOC stocks, ameliorate the nutrient content of soils and close nitrogen and phosphorus cycles at regional scales. However, depending on the waste collecting protocols of countries or regions, care needs to be taken with risk of contamination of soils with urban waste.

The enabling environment

Farmers and land managers are generally aware of agricultural and land management practices required to improve nutrient and manure management and they also provide valuable sources of empirical innovations. Optimization of current and contextualized practices requires technical and scientific support. Farmers and land managers need to be at the center of this science/stakeholders engagement.

The involvement of farmers and land managers is crucial to initiate and then maintain desirable practices for the long term, thus mitigating the risk of reversibility. Moreover, this enabling environment may include direct revenues associated with the implementation of practices improving SOC stocks, financial support, capacity building and policy incentives, such as payments for ecosystem services.

D) Key documents and papers for consideration at the workshop

FAO (2019). The International Code of Conduct for the Sustainable Use and Management of Fertilizers. Roma, FAO**:** 56 http://www.fao.org/3/ca5253en/CA5253EN.pdf

Grillot, M., Guerrin, F., Gaudou, B., Masse, D., Vayssières, J., 2018. Multi-level analysis of nutrient cycling within agro-sylvo-pastoral landscapes in West Africa using an agent-based model. Environmental Modelling & Software 107, 267-280.

Rumpel, C., Amiraslani, F., Chenu, C., Garcia Cardenas, M., Kaonga, M., Koutika, L.-S., … Wollenberg, E. (2019). The 4p1000 initiative: Opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy. *Ambio*. https://doi.org/10.1007/s13280-019-01165-2

Rufino, M.C., Tittonell, P., van Wijk, M.T., Castellanos-Navarrete, A., Delve, R.J., de Ridder, N., Giller, K.E., 2007. Manure as a key resource within smallholder farming systems: Analysing farm-scale nutrient cycling efficiencies with the NUANCES framework. Livestock Science 112, 273-287.

Smith, P., J. Soussana, et al. (2019). "How to measure, report and verify soil carbon change to realise the potential of soil carbon sequestration for atmospheric greenhouse gas removal." *Glob Change Biol*. https://doi.org/10.1111/gcb.14815

Wassenaar, T., F. Dumoulin, et al. (2016). Agricultural organic waste recycling to reduce greenhouse gas emissions. Climate change and agriculture worldwide. E. Torquebiau. Versailles, Quae, Cirad, Springer: 167-181.

Vayssières J., Rufino M.C., 2012. Managing nutrients cycles in crop and livestock systems with green technologies. In: Arcand Y. & Boye J.I. (Eds), Green Technologies in Food Production and Processing. Springer, New York, USA, p 151-182.

WOCAT Data base – The global Data base on Sustainable Land Management. https://qcat.wocat.net/en/wocat/

List of signatories

1. **ABDN**, the University of Aberdeen
2. **CAES,** College of Agricultural and Environmental Sciences, Makerere University (Uganda)
3. **CEA**, the French Alternative Energies and Atomic Energy Commission
4. **CEIGRAM**, the Research Centre for the Management of Agricultural and Environmental Risks of the Polytechnic University of Madrid
5. **CIMMYT**, the International Maize and Wheat Improvement Center
6. **CIRAD**, the French Agricultural Research Centre for International Development
7. **GASL** Global Agenda for Sustainable Livestock, FAO**,** Rome**.**
8. **IBC&SB**, Institute of Bioenergy Crops and Sugar Beet (Ukraine)
9. **IIASA**, the International Institute for Applied System Analysis
10. **IITA**, the International Institute of Tropical Agriculture
11. **INIA:** Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (spania)
12. **INRA**, the French National Institute for Agricultural Research
13. **IRD**, the French National Research Institute for Sustainable Development
14. **ISRIC**, the International Soil Reference and Information Centre - World Soil Information
15. **LRI**, Laboratoire des RadioIsotopes (Madagdascar)
16. **MSU**, the Lomonosov Moscow State University
17. **STC,** The scientific and technical committee of the 4p1000 initiative
18. **ULS**, The University of Life Sciences in Lublin (Poland)
19. **VAAS**, the Vietnam Academy of Agricultural Sciences